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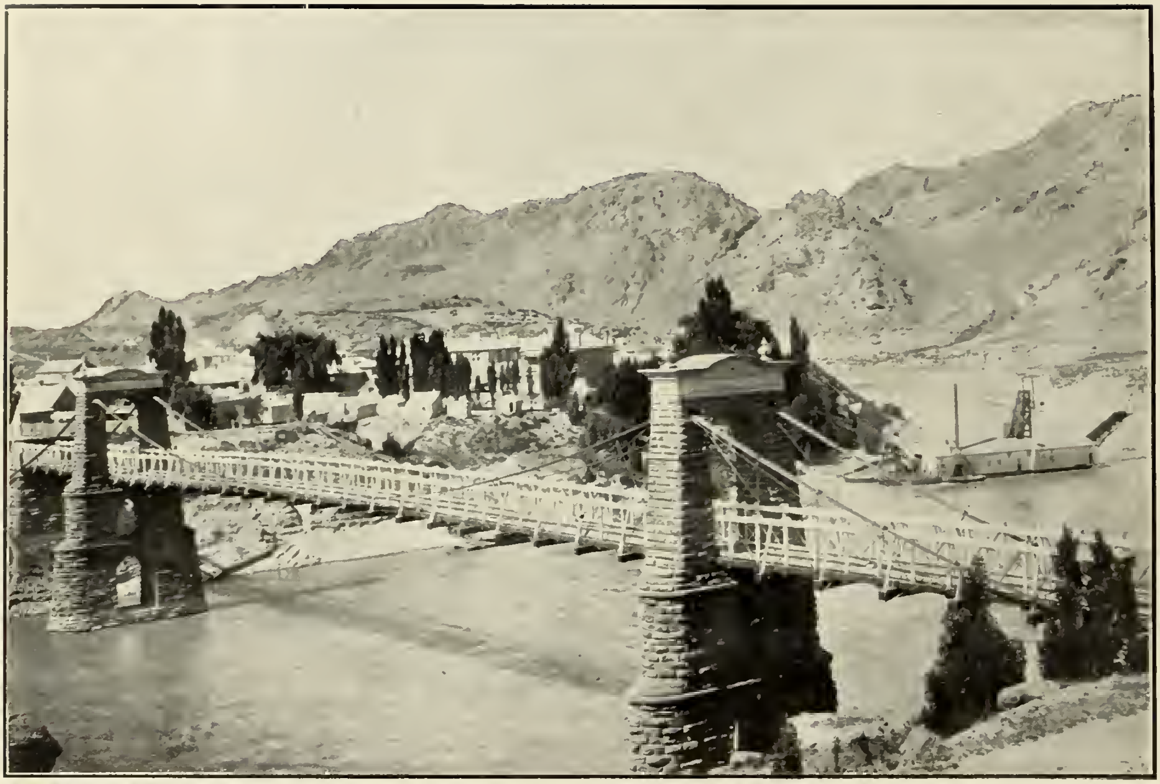

Alexandra South, showing Junction of Manuherikia River with the Clutha.

Department of Mines.

NEW ZEALAND GEOLOGICAL SURVEY.
(J. M. BELL, Director.)

BULLETIN No. 2 (NEW SERIES).

THE GEOLOGY OF THE AREA COVERED BY THE ALEXANDRA SHEET,

CENTRAL OTAGO DIVISION,

(INCLUDING THE SURVEY DISTRICTS OF LEANING ROCK, TIGER HILL, AND POOLBURN.)

Map
QE
348.2
B84
no. 2

BY

JAMES PARK, M. INST. M. AND M. (LONDON), M.A. INST. M.E., F.G.S. (LONDON),
DIRECTOR OF THE OTAGO SCHOOL OF MINES, PROFESSOR OF MINING AND MINING GEOLOGY IN THE UNIVERSITY OF OTAGO.

ISSUED UNDER THE AUTHORITY OF THE HON. JAMES McGOWAN, MINISTER OF MINES

NEW ZEALAND.
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1906.

LETTER OF TRANSMITTAL.

Otago University,
Dunedin, 2nd July, 1906.

Sir,—

I have the honour to transmit herewith the manuscript, illustrations, and maps of Bulletin No. 2 (new series), on the area covered by the Alexandra Sheet of the Central Otago Division.

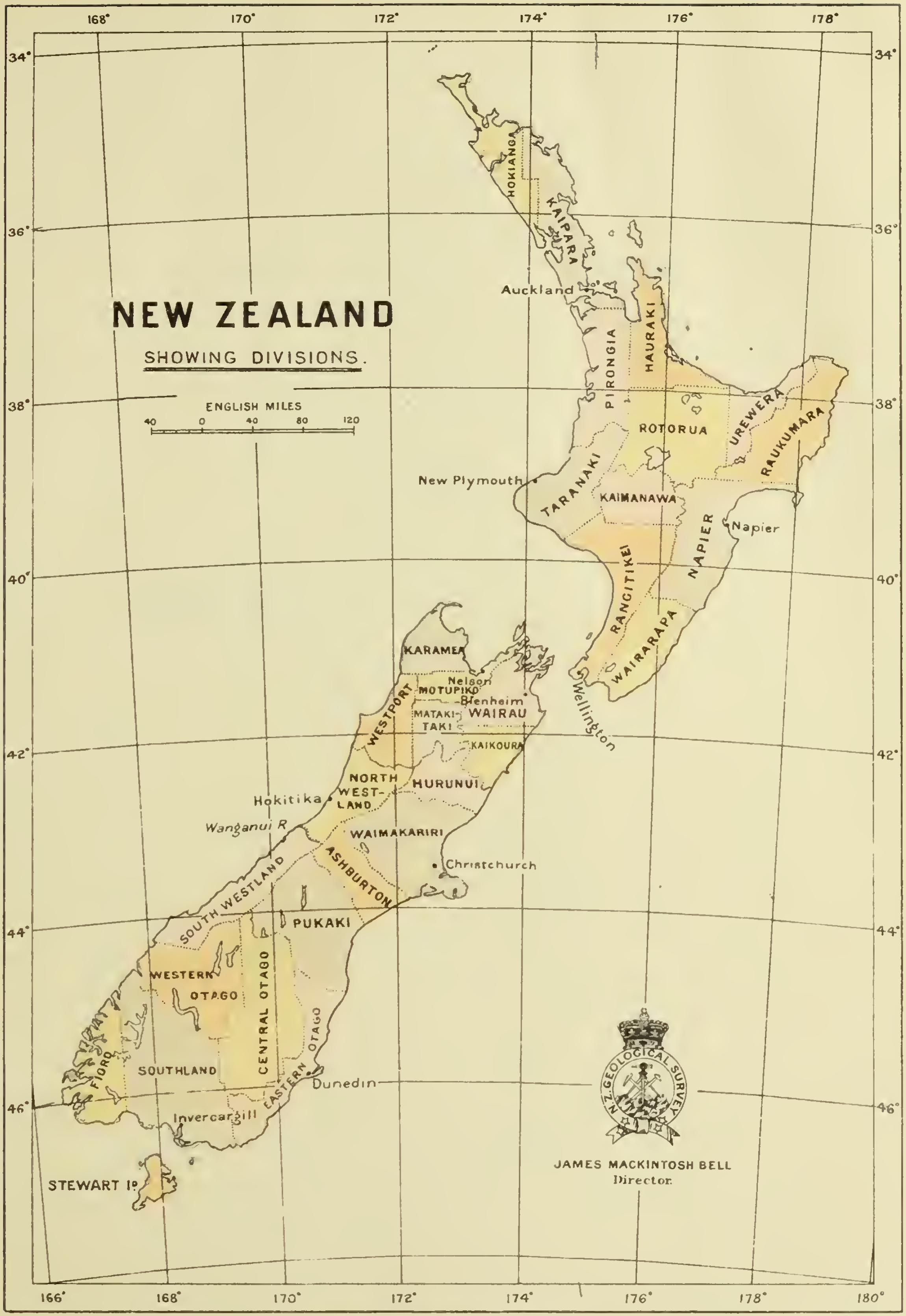
The report is accompanied by eleven maps and sections, and is illustrated with forty plates and eighteen diagrams scattered throughout the text.

The field-work was performed by myself and two student assistants during the five summer months of 1905–6.

This region is one in which the mica schist of Palæozoic age, the lacustrine beds in the old lake-basins of younger Tertiary age, and the detrital material derived from the erosion of the former and re-sorting of the latter contain deposits of economic value.

I have the honour to be,
Sir,
Your obedient servant,
JAMES PARK.

Dr. J. M. Bell,
Director Geological Survey,
Wellington.



NEW ZEALAND

SHOWING DIVISIONS.

JAMES MACKINTOSH BELL
Director.

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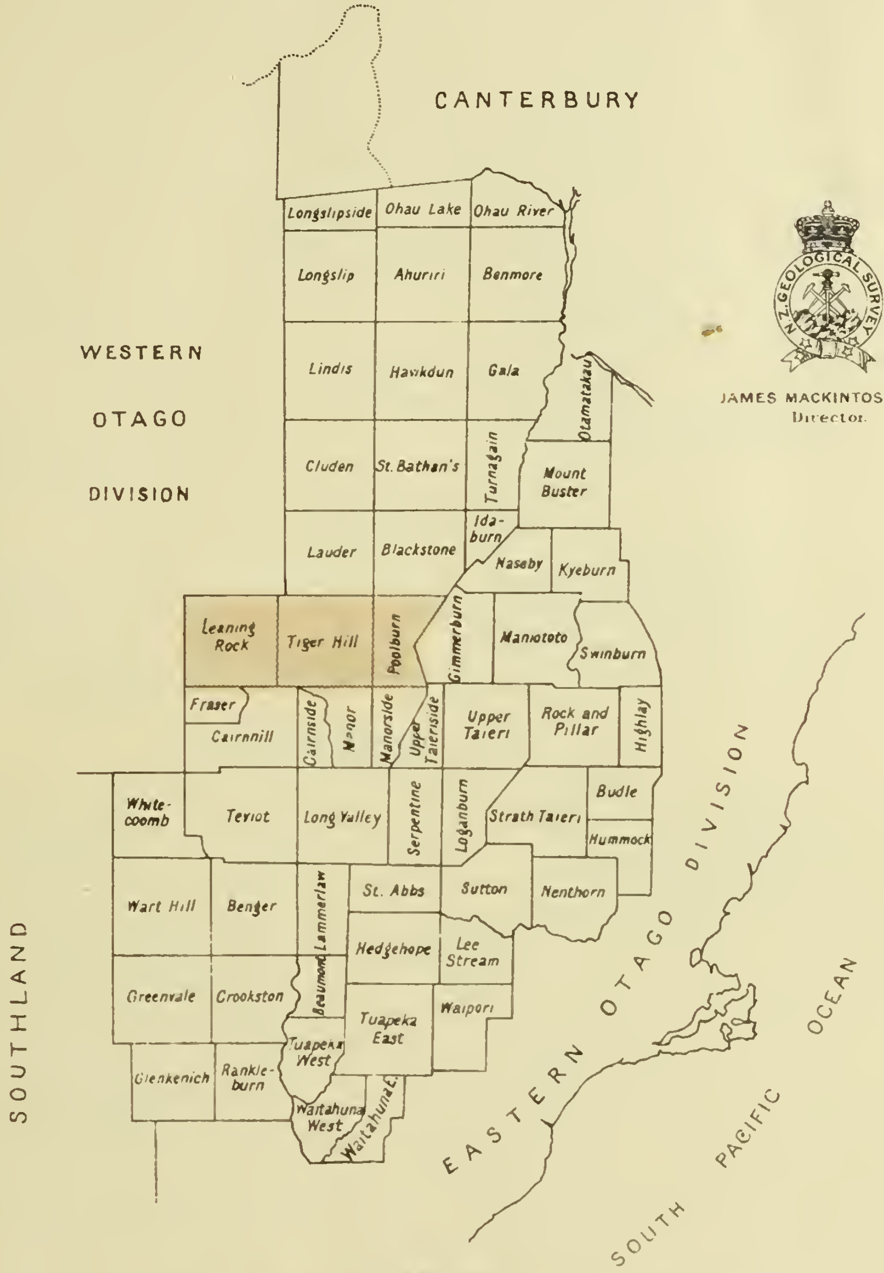

JAMES MACKINTOSH BELL
Director.

PLAN OF
CENTRAL OTAGO DIVISION
SHOWING SURVEY DISTRICTS

Districts dealt with in report
shaded thus ▭

— SCALE —
10 5 0 10 20 30 40
MILES

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BULLETIN No. 2 (NEW SERIES).

GEOLOGY OF THE AREA
COVERED BY THE
ALEXANDRA SHEET,
CENTRAL OTAGO DIVISION.

CHAPTER I.

GENERAL DESCRIPTION OF DISTRICT.

	Page		Page
Scope of the work	1	General geological structure	2
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THE area covered by the Alexandra sheet extends from Alexandra, along the valley of the Clutha, to a point a few miles below Cromwell, and from Alexandra along the Manuherikia Valley to Ophir, whence it reaches across Raggedy Ridge into Ida Valley. It lies nearly equidistant from the sea on both coasts, and includes the Survey Districts of Leaning Rock, Tiger Hill, and Poolburn.

This region possesses a many-sided interest. To the student of physiography it presents a field perhaps unrivalled in New Zealand for the study of mountain-building and the development of surface-forms. To the economist its attraction lies in the millions of gold won from its gravels, in the greater millions still to be won, in the store of coal buried in its plains. The farmer sees in it a land of promise : the soil is as fertile as the best on the famed Taieri Plains.

Central Otago is one of the driest parts of New Zealand. The rainfall is scanty and the subsoil porous. In their natural state the plains and terraces are often little better than a bare wilderness ; but water acts on the land like magic, transforming it into prosperous farms and fruitful orchards.

Although the rainfall is slight, the snow-fed rivers and streams which traverse the country provide a large and never-failing supply of water that could be made available for mining and irrigation purposes, or for the generation of power, by a comparatively small outlay of capital.

The country in its natural condition is quite destitute of trees and all forest vegetation.

A distinctive feature of this region is the extensive exposure of bare rock on the lower ranges and flanks of the mountains.

SCOPE OF THE WORK.

The work undertaken in the summer of 1905–6 included an examination of the geological structure of the district, of the physical features and surface-forms, of former glaciation, of the nature and extent of the gold-bearing drifts, coal-deposits, and metalliferous lodes, of the soil and water-supply, The topography is based on the maps of the New Zealand Survey Department. The topographical features shown on these maps were general rather than particular, and in most places lacking in the detail necessary for exact geological delineation. For this cause much time was spent in filling in the topography either by theodolite or compass traverse, or by inspection in the places where the settlement boundaries made this course possible.

The topography shown on the special sheets was filled in for the most part by traverse, and the contours fixed by levelling.

It will be found that the approach to accuracy is in proportion to the opportunity given for detail, which is mostly governed by the scale used.

The general maps have been printed on a scale of 1 in. to the mile, and the amount of detail introduced is that considered necessary to bring out clearly the salient points of the geology. Thus in the one-mile maps the minor subdivisions of the Manuherikia (lacustrine) series have been suppressed, and in some cases the superficial deposits of the valleys have been omitted where these would obscure the geological structure or the continuity of the underlying formation.

The sections are drawn to the same horizontal and vertical scale, and on these there is in some cases a suppression of detail. They are always drawn looking towards the north, north-west or north-east.

ACKNOWLEDGMENTS.

I wish to record my appreciation of the zealous assistance rendered in the field by my student assistants—Mr. R. A. Farquharson, M.Sc., in petrographical and topographical work, and Mr. Hugh R. Macdonald in topographical and mapping work. My acknowledgments are also due to Mr. W. E. McAdam, Mr. G. L. Cuthbertson, Mr. W. S. Laidlaw, Mr. L. B. Grimstone. Mr. James Pollock, Mr. A. Hunter, Mr. J. Smith. Mr. J. S. Dickie. and many others for their valued assistance. more particularly in respect to information relating to local details. Special thanks are due to Mr. Alexander McKay. F.G.S., for the beautiful photographs with which the chapter on petrography is illustrated, and to Mr. E. R. Green, Inspector of Mines, for data relating to the coal-mines.

GENERAL GEOLOGICAL STRUCTURE.

The prevailing rock throughout Central Otago is mica schist, which is generally interbedded with thick bands of chlorite schist. Quartz schist is not uncommon, and in one place there is a thin band of actinolite schist.

Igneous rocks are absent, or, if present. do not appear at the surface. The granites, syenites, and basic dyke rocks so well represented in the Pleistocene and younger gravels are strangers to the district, having been borne by water and ice from the mountainous region lying far to the westward.

The mica schist is overlain in the old lake-basins by a great thickness of fresh-water beds of probably later Tertiary age. These last are in their turn followed by glacier drifts, gravels and modified glacier drift. and gravels representing all ages from the Pleistocene down to the river-beds of the present day.

PREVIOUS GEOLOGIC WORK.

The first notice of the geology of Central Otago was made by Dr. Charles Forbes,* of H.M.S. "Acheron," in 1855. This writer, in a paper "On the Geology of New Zealand, with Note on its Carboniferous Deposits," mentions that the mountains in the centre of the province are composed of crystalline and metamorphic rocks.

Dr. W. Lauder Lindsay, in a lecture delivered at Dunedin in January, 1862, referred to the evidence of former glacier or ice action in New Zealand. At the same time he pointed out that the mica schist was the source of the gold found in the alluvial drifts of Otago. The mica schist was compared with the crystalline rocks in the Grampian Mountains in Scotland, and considered by him to be of Lower

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* Quart. Journ. Geol. Soc. xi, 521.

Silurian age. Lindsay divided the gold-bearing drifts into two series, the older of which included the lacustrine lignitic beds. He predicted that gold-mining was destined to become one of the permanent industrial resources of Otago. In October of the same year he read a paper "On the Geology of the Goldfields of Otago" before the British Association for the Advancement of Science, but, unfortunately, no record appears to have been kept of it.

From this it will be seen that all the salient points of the geology of Otago were noted by Lindsay as far back as 1862. From then till now the work of successive geologists who have examined the country has been concerned chiefly with matters of detail. Lindsay's generalisations still stand unassailed. They are a monument of careful field observation and clear geologic deduction.

Sir James Hector, at that time Provincial Geologist, examined the Manuherikia Valley in the winter of 1862. In his report, published in the Provincial Government *Gazette* of the 3rd September, 1862, he describes the schists of Central Otago, and confirms Lindsay's opinion that they are the source of the alluvial gold. He describes the interior lake-basins, the contents of which he divides into older and newer Tertiaries. He describes the older Tertiaries as "the deposits which gradually filled up the depression as it passed through the successive stages of submergence, from an estuary-like arm of the sea to a deeply excavated submarine valley. They invariably consist at the base, where they rest on the schist, of strata which indicate the neighbourhood of dry land at the period of their formation supporting a vigorous vegetation which has been preserved to us as brown coal, associated with finely assorted beds of clay and gravel indicative of current-action in shallow water. Elsewhere in the province marine shells have been discovered along with these beds. Over this group have been deposited strata of sand and conglomerate formed of materials derived from the schistose rocks. The period of the greatest depression of the land, which corresponds with the close of what I term the 'older Tertiary epoch,' was marked in some districts of the province by volcanic eruptions. . . . It was with the first display of volcanic activity that the elevation of the land commenced, and although, as is always the case, this elevatory movement was accompanied by degradation of pre-existing strata rather than by the formation of new deposits, yet under favourable circumstances this very degradation gives rise to local deposits, which are those I shall provisionally term the 'newer Tertiaries.' During this period the rock-bound basin afterwards to be drained by the Taieri and Molyneux Rivers became converted into a system of lakes, connected by streams, which slowly excavated terraces, and deposited in a more perfectly assorted form the materials which compose the plateau. . . . As the main exit channels of the basin were deepened, the lakes were in time drained, and the materials again sorted by the erosion of the streams."

In 1864 Sir James Hector prepared a manuscript geological map and section of Otago and Southland. The map is now in the Otago Museum, and the section in the Otago University School of Mines. The table of reference used in connection with the subdivisions shown on the map is as follows:—

I. Alluvium.
II. Lacustrine Tertiary strata of interior basins.
III. Pliocene marine Tertiaries.
IV. Plastic clay and brown coal series.
V. Eocene ferruginous shales with sandstones.
VI. Upper Secondary coal formation.
VII. Lower Secondary. Te Anau series. Indurated shales with calcareous concretions.
VIII. Diorite and aphanite slates.
IX. Kakanui series. Arenaceous clay slates.
X. Mica slate and cleaved slates.
XI. Contorted and foliated schists.
XII. Chlorite and actinolite schist.
XIII. Old clay slates with mica schist.

XIV. Gneissic and crystalline metamorphic rocks.
XV. Granite.
XVI. Syenite.

In 1864 and 1865 Sir James Hector* published a paper "On the Geology of the Province of Otago, New Zealand." This paper is of great value, as it was the first attempt to present a systematic classification of the rock formations of Otago. In it he gives a diagrammatic view of the rock structure from the west to the east coast, and distinguishes the following formations :—

I. Recent.
  1. Alluvial. River silts, shingles, and deltas.
  2. Lacustrine. Exposed by gradual drainage of lakes.
  3. Estuarine or Littoral. Exposed by emergence of coast-line.
II. Pleistocene. (Newer gold drifts.)
  1. Lacustrine. In basins in the interior.
  2. Glacial. Moraine deposits and loess.
III. Pliocene. (Great gold drift.)
  1. Sand, &c., in basins in the interior (with lignite).
  2. Coastward deposits.
    a. Volcanic and tufaceous deposits.
    b. Sands and clays.
IV. Miocene.
  1. Oamaru, or calcareo-arenaceous series.
  2. Moeraki, or argillaceous series (brown coal).
  3. Waitaki. Arenaceous.
V. Carbonaceous series. Estuarine strata, with conglomerates, sandstones, shales, and brown coal of fine quality.
VI. Te Anau series. Porphyritic conglomerate, wacke, claystones, glossy slates and diabase, porcellanite.
VII. Kaihiku series. Quartz, clay shales, sandstone, diorite slate, black cross-cleaved slate, siliceous and true clay slate.
VIII. Foliated schists.
  1. Grey argillaceous. Kakanui series.
  2. Blue clay slate. Micaceous or chloritic.
  3. Contorted feldspathic schist.
    All these are more or less impregnated with infiltrated quartz, and are auriferous.
IX. Gneiss-granite. Quartzose with garnets, or feldspathic.

In 1865 Dr. Lindsay read a paper on the Tertiary coals of New Zealand to the Royal Society of Edinburgh, in which he refers to the lignitic lacustrine beds of Central Otago.†

In 1866 there appeared the Jurors Reports and Awards of the New Zealand Exhibition held in Dunedin in 1865, in which are given the analyses of different Otago coals and lignites made by Mr. W. Skey, Analytical Chemist to the Geological Survey of Otago.

In 1868 Mr. John Buchanan, F.L.S., read a paper to the Philosophical Society of Wellington "On the Geology of the Country between the Lower Clutha and Mataura Rivers." This paper does not appear to have been published.

In the second volume of the "Transactions of the New Zealand Institute" there is an abstract of four lectures delivered by Sir James Hector‡ in the Colonial Museum in 1869 "On Mining in New

---

* Geol. Mag., 1864, p. 233 ; Quart. Journ. Geol. Soc., vol. xxi, p. 124 ; and Phil. Mag., vol. xxix, p. 157.
† *The Geologist*, vol. vi, p. 143.
‡ Trans. N.Z. Inst., vol. ii, 1870, p. 361.

Zealand." In this paper he gives a summary of the geology of New Zealand, based mainly on his classification of 1864, already quoted.

In 1872 Sir James Hector[*] published a report on the Clutha and Green Island coalfields. In the same year Captain Hutton[†] read a paper before the Wellington Philosophical Society in which he places the time of the last great glacier period in New Zealand in the older Pliocene, as opposed to both Sir James Hector[‡] and Sir Julius von Haast,[§] who contended for a Pleistocene extension.

In a paper "On the Extinct Glaciers of New Zealand," Mr. W. T. L. Travers[‖] refers only in general terms to the ancient glaciers of Otago. He does not appear to have had any personal knowledge of Central Otago at the time he wrote his paper.

In 1874 Mr. J. T. Thomson[¶] read a paper before the Otago Institute "On Glacier Action in Otago," in which he contended that the whole Island was at one time enveloped in a sheet of moving ice. His argument in favour of this is not very conclusive.

In the same year Captain Hutton published in the *Geological Magazine* a table of the sedimentary formations of New Zealand, in which the lacustrine beds of the Manuherikia Basin are referred to the Wa'nganui formation of newer Pliocene age, the ancient glacier-deposits to the older Pliocene, and the newer glacier-deposits to the Pleistocene. This view is reaffirmed in 1875 in his monograph on the geology of Otago, pp. 66 and 67. In this work (p. 69) he refers to the conspicuous moraine at the lower end of the Kawarau Gorge, a few miles from Cromwell, but says that he had seen no glacier-deposits below Cromwell. From this it would appear that he had in some way overlooked the great moraine at Clyde.

Sir James Hector, in his "Outline of New Zealand Geology," 1886, places the lignitic beds of Central Otago in the Pliocene.

The writer[**] in 1888 examined the Pleistocene gold-bearing gravels at Galloway Flat and Ophir; the gold-bearing lacustrine beds at Ida Valley and German Hills; the mine-workings at Green's Reef, Ophir; the antimony lode at Alexandra South, &c.

Mr. H. A. Gordon,[††] in his annual report on the goldfields in 1890, states that the old quartz-gravel drift at Tinker's lies at a considerable angle against the false or Maori bottom, and dips towards the schists of the main range. In the following year he says there seems to be a comparatively narrow run of ground following the foot of the range, but how far has not been ascertained.[‡‡]

Mr. A. McKay, in his "Report on the Older Auriferous Drifts of Central Otago," published in 1897, mentions the steeply inclined clay, shale, lignite beds, and quartz grits at Waikerikeri Valley, five or six miles from Clyde. He noticed the large angular blocks of schist in the high gravel terraces at the lower end of the valley, which, he says, lead to the belief that the higher part of the terraces were deposited by glacier action (p. 46). In this report Mr. McKay also refers to the lacustrine beds exposed at Chatto Creek, Tinker's, &c. (p. 48, *et seq.*).

In his paper on the "Gold-deposits of New Zealand," 1903, reprinted from the *New Zealand Mines Record*, Mr. McKay makes brief mention of the older and younger gold-bearing drifts in Central Otago. The gold in the younger gravels is traceable, he thinks, to the older lacustrine quartz drifts of the old lake-basins (p. 54).

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[*] Geol. Reports and Explorations, 1871–72, p. 165.

[†] Trans. N.Z. Inst., vol. v, 1872, p. 384.

[‡] Hector, Journ. Roy. Geol. Soc., 1864, p. 103; Geol. Mag., 1870, p. 70; N.Z. Ex. Jur. Rep., p. 263; Trans. N.Z. Inst., vol. ii, p. 372; Quart. Journ. Geol. Soc., 1865, p. 128.

[§] Haast. "Canterbury Plains," p. 14; and Quart. Journ. Geol. Soc., vol. xxi, p. 131.

[‖] Trans. N.Z. Inst., vol. vi, 1873, p. 297.

[¶] Trans. N.Z. Inst., vol. vi, p. 309.

[**] Park, Geol. Reports and Explorations, 1888–89, p. 17–35.

[††] Report on the Mining Industry of New Zealand, 1890, p. 76.

[‡‡] Reports on the Mining Industry of New Zealand, 1891, p. 70.

CHAPTER II.

PHYSIOGRAPHY.

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MOUNTAINS AND RANGES.

FROM any elevated position in Central Otago the sky-line is seen to be bounded by table-topped mountains, some of which are remarkably even along the crest, others gently undulating, but presenting no abrupt heights deserving the name "monadnock," with the exception of Mount St. Bathans and Mount Ida, both of which lie outside the limits of the Alexandra sheet. These plateau-like mountains are manifestly the remains of an uplifted peneplain. If the intervening valleys and ridges were filled up to the level of the mountain plateau, the worn-down and dissected base-level of Central Otago would be restored.

This ancient peneplain can still be clearly traced throughout eastern Otago from the main divide to the eastern shore, and from the Waitaki to Southland. It is uptilted, and slants gently from the alpine ranges to the south-west.

The writer,* in a paper on "The Marine Tertiaries of Otago and Canterbury," showed that this differential uplift affected the whole of the South Island, being caused by an accelerated movement along the main axial divide, accompanied by retardation or drag along the east coast.

The upland portion of this peneplain, of which the Alexandra sheet forms but a small portion, has been deformed into a number of parallel ranges, athwart the ends of which are transverse ranges. The parallel ranges are separated from each other by deep basins, which are filled with a great accumulation of lacustrine strata, fluviatile and glacier drifts.

The seaward portion of the plateau is not much deformed, but is scored by the deep, narrow courses of the Taieri, the Clutha, and their tributaries.

The upland plateau-like mountains vary from twenty to forty miles long, and maintain a height generally between 5,000 ft. and 5,500 ft. above sea-level. They possess no great descending spurs or ridges, and no foothills. The boundary between the valley and the ascending slope of the mountain-range is in most cases almost straight, following a line of normal fracture or dislocation running parallel with the base of the mountain—that is, coincident with the longitudinal axis of the mountain-range.

In these table-topped ranges and intervening basins we have conspicuous examples of "block mountains," probably not less remarkable than the ranges of the great basin between the Sierra Nevada and Wasatch Mountains, and those of Vosges and Black Forest.

Professor Eduard Suess, the distinguished Austrian geologist, has suggested that plateau-like mountains owe their height not to their own uplift, but to the subsidence of the surrounding lower areas. On the other hand, Professor W. M. Davis, the well-known American physiographer and geologist, contends that mountains of this class are uplifted blocks of an ancient peneplain. His argument is based on observations made by himself in the western ranges of the Tian Shan mountain system of Turkestan. He mentions the Bural-bas-tan, in the neighbourhood of Son-kul Lake, as a notable example of a block mountain formed by uplift.

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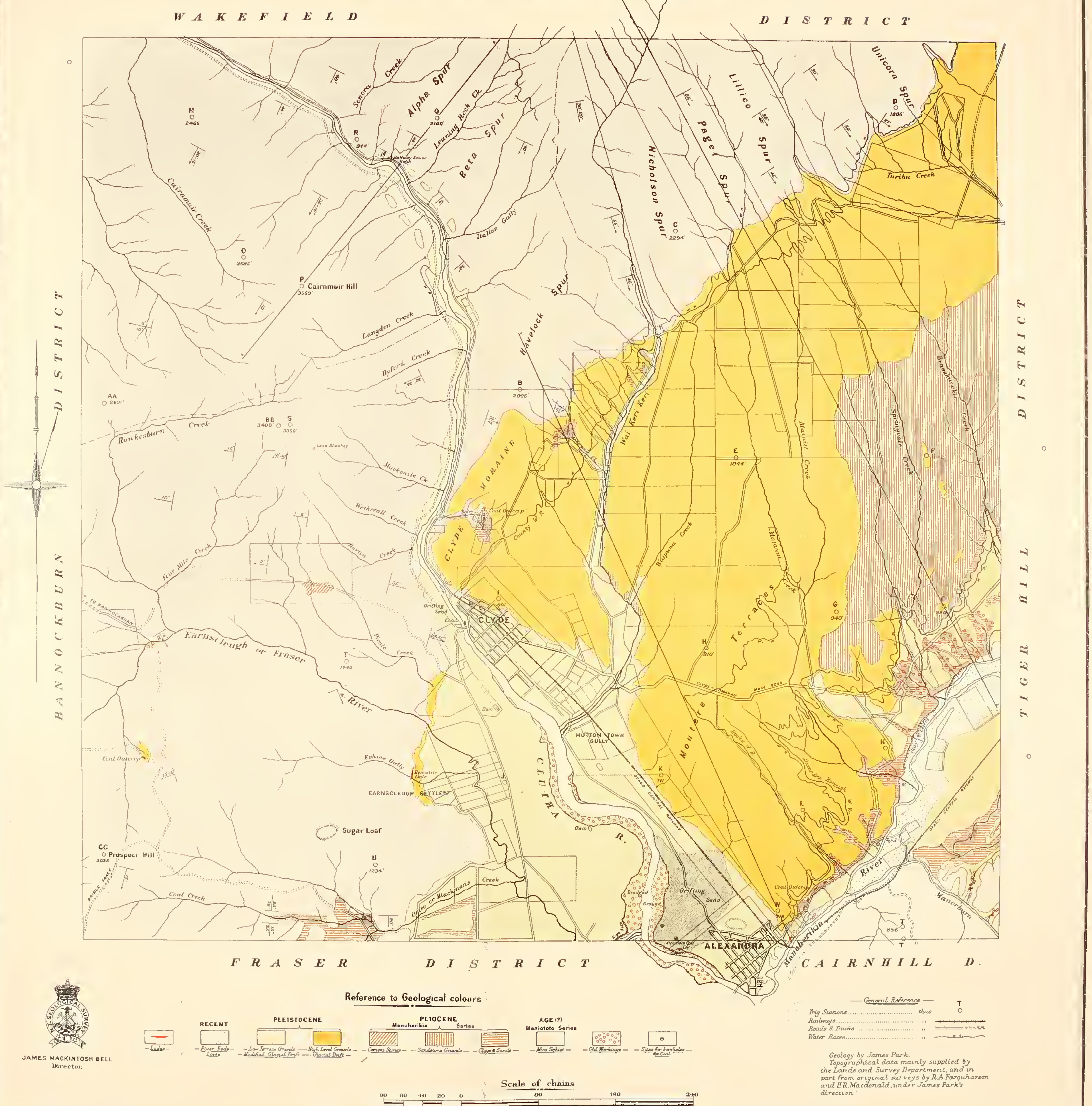
* Park, "On the Marine Tertiaries of Otago and Canterbury, with Special Reference to the Relations existing between the Pareora and Oamaru Series" (Trans. N.Z. Inst., vol. xxxvii, 1904, pp. 489–551).

Geological Map of
LEANING ROCK DISTRICT



JAMES MACKINTOSH BELL
Director.

Geology by James Park.
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A. Farquharson and H.R. Macdonald, under James Park's direction.

G.P.W. 6417 JULY 1906.

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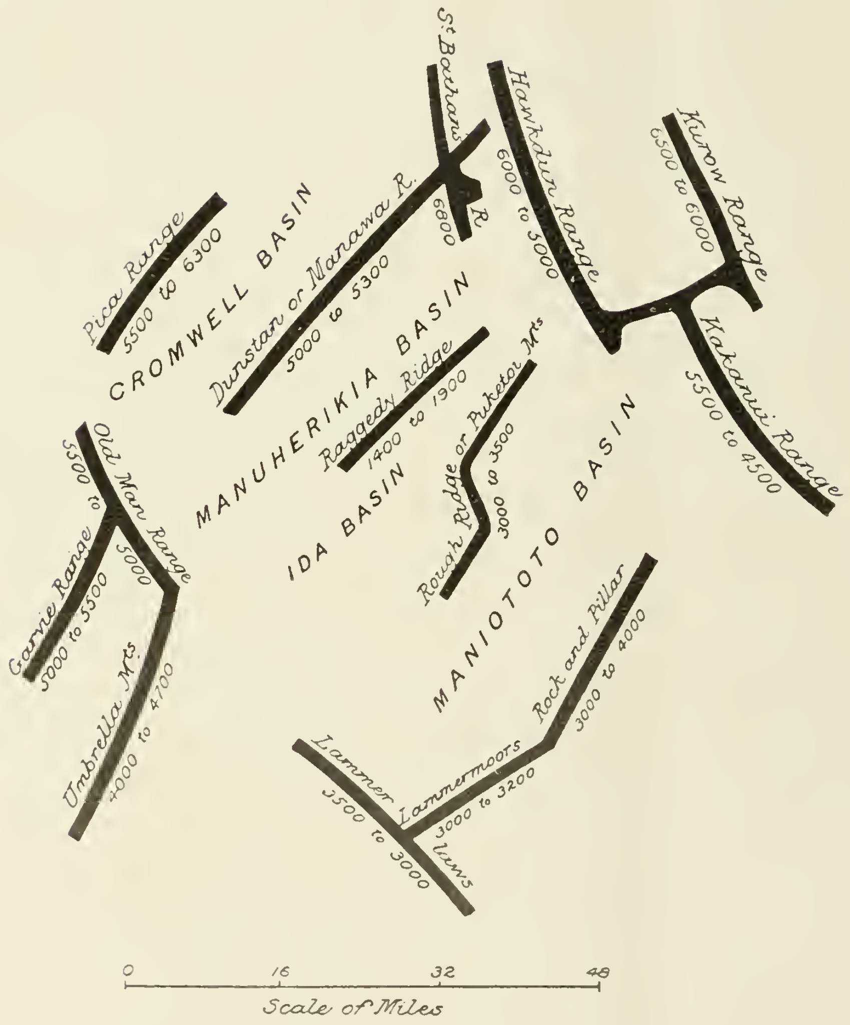
Plate I

THE BLOCK MOUNTAINS OF CENTRAL OTAGO.



While it may be true that some mountains are the result of uplift, it may equally be true that others are left as *horsts* by the subsidence of surrounding areas. The study of a great faulted coalfield in which the comparatively horizontal coal gives a measure of relative movement affords conclusive evidence that extensive areas which have been elevated during epeirogenic uplift have subsided with moderate or no tilt from the normal in parts bounded by more or less parallel dislocations.

So far as the genesis of the block mountains of Central Otago is concerned, it seems easier to believe that the intervening basins are *graben*, or strips of subsidence, than to suppose that these strips remained stationary while the block mountains and seaward plateau were uplifted to their present height.

Moreover, these basins are filled with a great pile of lacustrine strata the character of which indicates shallow-water conditions of deposition from the bottom to the top. To obtain these shallow-water conditions we must suppose either that the basins were *graben* and subsided at approximately the same rate as the filling, or that the cutting-down of the outlet kept pace with the uplift of the surrounding mountains. The former view seems to present fewer mechanical difficulties.

I shall now refer more particularly to the block mountains in or near the district forming the subject of this report.

First we have the Pisa Range, lying south of the high, deeply dissected alpine region that extends northwards from Lake Wakatipu. The general trend of the range is about north-east.

South-east of the Pisa Range there are the Dunstan Range, Raggedy Range, Puketoi Range (commonly called "Rough Ridge"), and, lastly, the Rock and Pillar Range, with its continuation, the Lammermoor Mountains. All of these are more or less parallel ranges. They are separated from each other by old lake-basins, along the margins of which there are great normal faults or dislocations. Thus between the Pisa and Dunstan Ranges lies the Cromwell Basin; between the Dunstan and Raggedy Ranges lies the Manuherikia Basin; between the Raggedy and Puketoi Ranges lies the Ida Basin: between the Puketoi and Rock and Pillar Ranges lies the Maniototo Basin.

South-east of the Rock and Pillar Range and its southern continuation, the Lammermoor Range, lies the seaward plateau traversed by the Taieri River and its tributaries.

The relative position of these mountains and intervening basins is shown in the sectional diagram below.

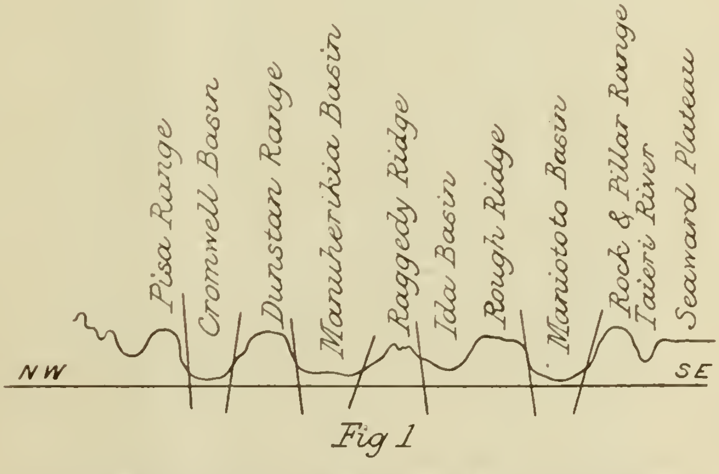


FIG. 1.—SECTION ACROSS BLOCK MOUNTAINS AND OLD LAKE-BASINS.

The Hawkdun Range runs about north-west, and blocks the upper end of the great Manuherikia Basin, its trend being at right angles to the parallel ranges already described. It abuts against the

Dunstan Mountains, from which it is separated by the narrow gorge of the Upper Manuherikia River From any part of the Lower Manuherikia Valley the sky-line of the Hawkduns for a distance of twenty miles appears as even as the ridge of a house.

The Old Man Range, lying athwart the lower end of the Manuherikia Basin, trends about north-north-east. Like the Dunstan and Hawkdun Mountains, it is table-topped; but unlike them it sends off to the southward and northward side table-topped prolongations, which slope gently to the south-west, gradually descending by a uniform gradient from a height of 5,500 ft. above sea-level at the Carrick Range to 4,000 ft. at the south end of the Umbrella and Garvie Mountains.

The Pisa, Dunstan, Raggedy, Puketoi, Rock and Pillar, and Old Man Ranges are composed of mica schist, and the transverse Hawkdun Mountains of mudstones and grauwacke.

The relative position and orientation of these plateau-like ranges are shown in Plate I. The figures indicate the general height of the summit of the range expressed in feet.

There are one or two points on each range which attain a somewhat greater height than the average elevation of the table-topped crest. Thus on the Pisa Range we have Mount Pisa, 6,327 ft.; on the Dunstan Range, Mount St. Bathans, 6,837 ft. The rise of Mount Pisa is hardly perceptible to the eye. On the other hand, Mount St. Bathans stands 1,500 ft. above the general level of the Dunstan Range, but does not form a very prominent object when the whole range is seen in perspective from a neighbouring height. It is a remnant of the ancient higher land from which the great peneplain was excavated. and is all that now remains of a giant monadnock that formed a supporting buttress to the north-east shoulder of the Manawa Mountains.

RIVERS.

The Cromwell Basin is drained by the Clutha and Kawarau Rivers; the Manuherikia Basin by the Clutha, Fraser, and Manuherikia Rivers; the Ida Basin by the Poolburn and Ida Streams; and the Maniototo Basin by the Taieri River.

The Cromwell and Maniototo Basins are outside the area examined on this occasion, and will be dealt with later on.

MANUHERIKIA BASIN.

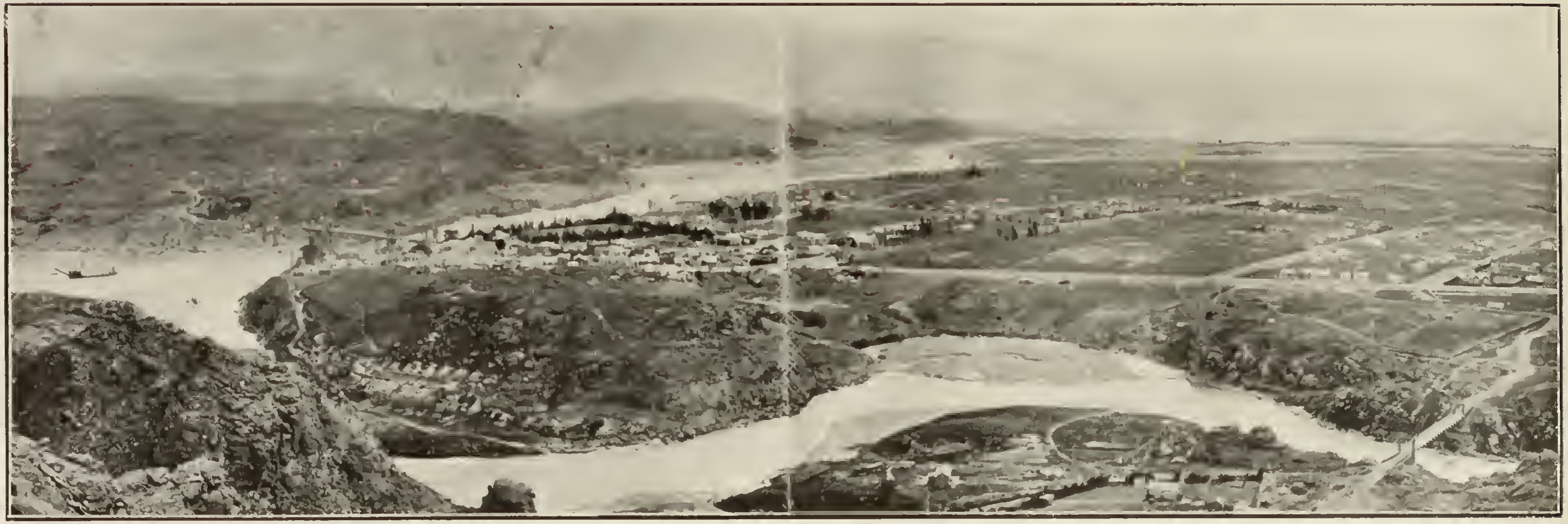
This basin extends from the flanks of the Old Man Range to the Hawkdun Mountains, a distance of nearly fifty miles. It varies from six to eight miles wide. The lower end of the valley is drained by the Clutha River, the middle and upper parts by the Manuherikia.

The valley rises from 500 ft. above sea-level at Alexandra to 1,200 ft. at the upper end. The Manuherikia runs along the east side of the basin—that is, close to the foot of Raggedy Range—and as a result of this the slope of the plains and terraces composed of the later drifts is from the Dunstan Range towards the Manuherikia.

The floor of the old basin is occupied by a great thickness of lacustrine deposits, with lignite at the base. In the lower end of the basin the lacustrine beds have been scoured out by the Clutha down to the lignite. In the middle part of the basin they lie nearly horizontal or dip gently towards the Hawkduns. Here they form the gracefully sculptured Merton and Magdalen Hills, in the middle of the valley, which rise to a height of 1,800 ft. above the sea, or nearly 1,000 ft. above the floor of the valley.

On the denuded surface of the Pliocene strata there rests a great pile of Pleistocene gravels and glacier drift forming the high terraced plains that slope from the foot of the Dunstan Range towards the Manuherikia River on the east side of the valley.

Both the Manuherikia and Clutha have formed high terraces along their course, largely composed of re-sorted material derived from the Pleistocene drifts forming the high-level terraced uplands of Moutere.



Alexandra South, showing Manuherikia River in the Foreground.

[Photo by G. F. Griffiths.

Great Faults.

The Manuherikia Basin is traversed by two great faults, one on each side—namely, the Waikerikeri fault, which follows the foot of the Dunstan Range, and the Manuherikia fault, which follows the east bank of that river.

The Waikerikeri fault runs north-east (true bearing), and is practically vertical from one end to the other. It can be traced at various points along its course of forty miles from near Clyde to St. Bathan's. The mica schist and the lacustrine beds are faulted so as to be vertical, and apparently conformable, as shown in Fig. 2.

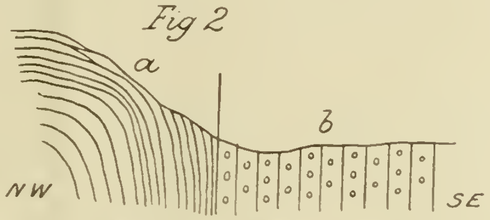


FIG. 2.—SECTION ACROSS WAIKERIKERI FAULT.
a. Mica schist. *b.* Lacustrine beds.

The manner in which the schists have been dragged down by the fault is very remarkable, and is seen to great advantage in the gorge of the Waikerikeri leading up to Leaning Rock. The great displacement of the lacustrine beds shows that movement has taken place along the fault since the Pliocene.

The Manuherikia fault is marked by one, and sometimes two or three, parallel lines of dislocation, generally contained within a distance of 50 yards. The fault fractures traverse the schist along the foot of the range, and are generally filled with hard chalcedonic quartz from 1 in. to several feet thick, in many places presenting finely polished and slickensided surfaces. The lacustrine beds have been entirely removed by denudation along the track of the fault fractures, and for this cause it is impossible to determine to what extent they were effected by the faulting. It cannot even be told whether they were affected at all—that is, the faulting may have taken place before they were deposited.

Origin of Lake-basins.

The Manuherikia and adjoining inland basins are filled with beds which are overlain unconformably by fluviatile drifts and glacier moraines formed during the Pleistocene period. The basins existed long before the greatest extension of the glaciers. Manifestly, their origin cannot be ascribed to glacier erosion. Clearly, we must conclude either that the basins are ordinary valleys of erosion blocked by the uplift or tilting of one end, or that they are areas of subsidence caused by faulting. Take the Manuherikia Basin: it is bounded on each side by great faults. On the west side the Pliocene fresh-water beds are tilted on end, thus proving that extensive faulting has taken place along the foot of the Dunstan Range since the deposition of these beds. Moreover, we know that the thickness of the beds exceeds 1,000 ft., while the character of the sediments indicates that they were laid down in comparatively shallow water. The inference to be drawn from these facts is that deposition began in a shallow but sinking basin in which the rate of deposition kept pace with the rate of subsidence.

History of Manuherikia Basin.

The floor of the basin is occupied by a pile of Pliocene lacustrine strata, the total thickness of which at one time greatly exceeded 1,000 ft. At Waikerikeri the stripping of the surface soils and gravels by hydraulic sluicing has exposed to view one of the best sections of these beds obtainable in any part of the valley. Here we have a thickness of 933 ft. of sediments in an unbroken sequence of exceptional clearness. At the base, abutting against the mica schist, there are 460 ft. of quartz sands, clays, and silts enclosing a seam of impure lignite near the base. Over these fine sediments come 138 ft. of loose quartz grits and gravels, which are in turn followed by 335 ft. of well-rounded sandstone gravel. Thus we find that the sediments become coarser as we ascend in the series.

The great thickness of fine material forming the lower member indicates that quiet conditions of deposition prevailed for a considerable time from one end of the basin to the other. Manifestly, no large rivers or torrential streams drained into the basin. The material is such as would be derived from the slow weathering of a neighbouring land-surface of moderate relief. At what end of the basin the outlet existed during the deposition of the lower and middle quartzose members of the series is at present unknown.

The presence of the seam of lignite near the base of the series shows that, after the first sediments had levelled the floor of the basin, a vegetation which included forest trees established itself and grew uninterruptedly for a comparatively long period; at any rate, long enough to permit the accumulation of sufficient vegetable matter to form a seam of lignite in some places over 30 ft. thick. During this period of vegetable growth the land must have remained stationary; or, if subsidence was in progress, it must have been extremely slow.

We have seen that the sediments become coarser as we ascend. The appearance of the coarse gravels marked the advent of a new agency in the cycle of deposition. Hitherto the sediments were composed of quartzose matter mainly derived from the surrounding mica schists. From this onwards the material is composed of grauwacke and mudstones derived from the Hawkdun Mountains, lying across the upper end of the basin. Here we have the first clear evidence of the existence of the Manuherikia River.

The Manuherikia poured its gravels into the lake until the basin was filled up, the new flood-level being a great shingle plain extending from one side of the valley to the other. The outlet of the basin was now, and had been for some time, at the south end, near the present site of Alexandra. It was without doubt the cutting of this new outlet that enabled the Manuherikia River to transport its load to the southward and successfully complete the reclamation of the lake-basin.

How long the Manuherikia remained in sole possession of the basin after the filling-in is not quite clear. It was probably not long after this, however, that the Clutha burst into the valley and began a new cycle of events, in which it has played a prominent part up to the present day.*

The first work of the Clutha was destructive. It began at once the cutting-down and removal of the newly formed and loosely compacted lacustrine beds along the lower end of the valley. At this time it flowed at a higher level than at present, and we have abundant evidence that the scouring influence of its rapid-flowing waters was felt as far as Springvale.

The Clutha River, while eroding the Pliocene lignitic beds and transporting its load towards the sea, was at the same time cutting down and regrading its bed, and in so doing was lessening its own power as an agent of erosion. The broad rock platforms or terraces at the outlet between Alexandra and Bald Hill Flat, 1,000 ft. or more above the present river-bed, still remain to mark the different flood-levels of the ancient Clutha.

The violence with which the Clutha attacked the lacustrine beds and cut down its own channel was the cause of its own undoing. With the decreasing velocity its carrying-power in time became so

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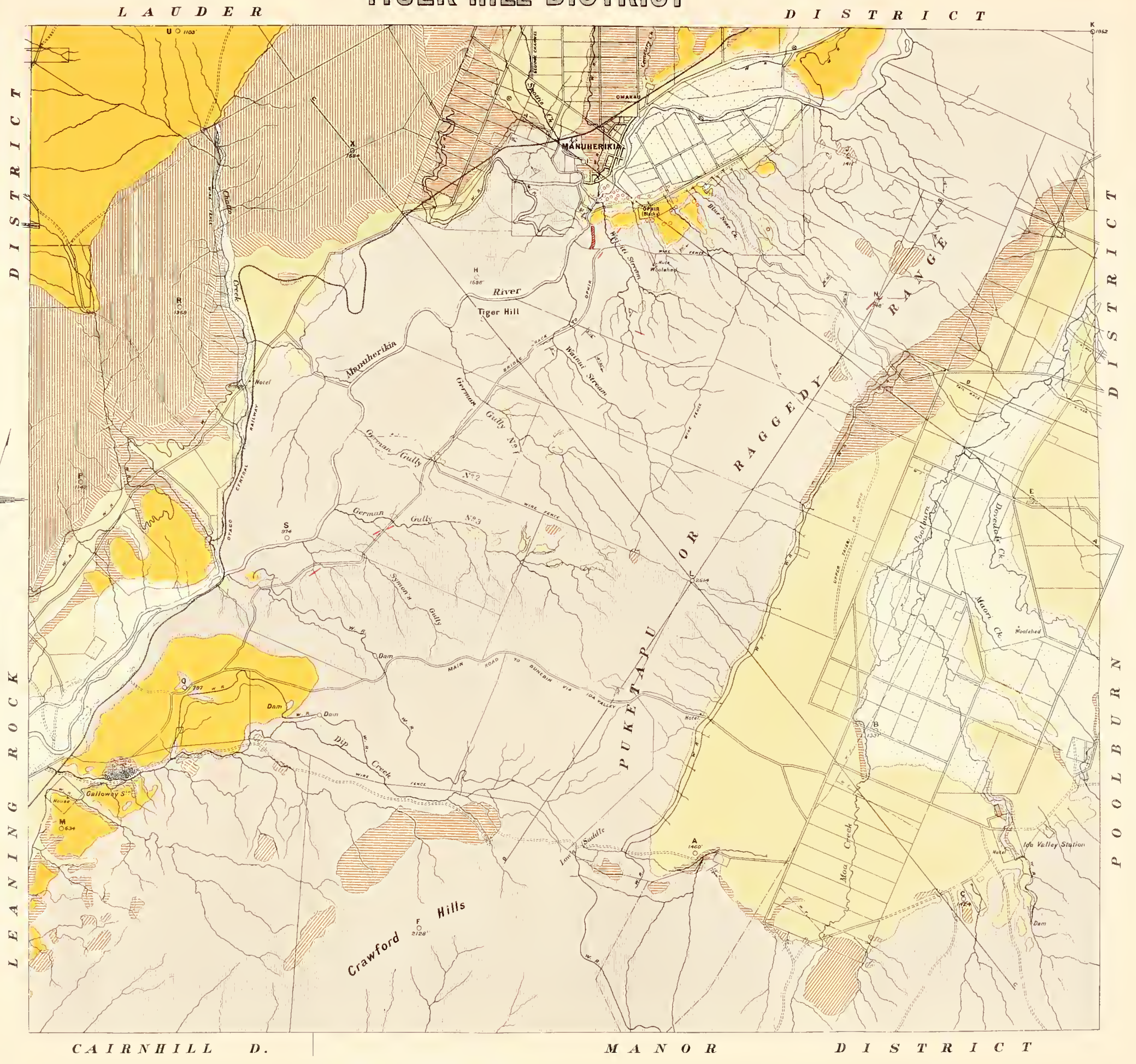
* In 1875 Captain Hutton, in the "Geology of Otago," p. 91, expressed the opinion that the outflow of the Clutha from the Cromwell Basin was across the Bannockburn Saddle into the Fraser River, and thence into the Manuherikia Basin. I made a special investigation of this point, and in doing so examined the terrace gravels in the upper part of the Fraser opposite the Bannockburn Saddle. These gravels I found consist entirely of mica schist, and contain none of the grauwacke or basalt which everywhere distinguishes the Pleistocene gravels of the Clutha. On the contrary, a careful survey of the Fraser watershed led me to the belief that the upper part of that river, when it ran at a higher level, actually flowed into the Cromwell Basin by way of the Bannockburn.

To accompany Bulletin No 2, Alexandra Sheet, Central Otago Division.

Geological Map of
TIGER HILL DISTRICT



CAIRNHILL D. MANOR DISTRICT

Reference to Geological colours

RECENT	PLEISTOCENE		PLIOCENE Manuherikia Series				AGE ? Maniototo Series			
Loess River Beds	River Terraces Modified Glacial Drift	High-level Terraces Glacial Drift	Cement Stones	Sandstone Gravels	Quartz Drift	Clays & Sands	Mica Schist	Actinolite Schist	Old Workings	Sites for Boreholes for Coal

Lodes

JAMES MACKINTOSH BELL
Director.

Scale of chains

80 60 40 20 0 80 160 240

General Reference.

Roads and Tracks .... . thus
Railways ... . "
Trig. Stations .... " A ○1460
Water Races. .... " W R

Geology by James Park
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A.Farquharson and H.R. Macdonald, under James Park's direction.

Drawn by G. P. Wilson

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enfeebled that it was no longer able to transport its load beyond the confines of the basin. Hence it now became a builder, and, with the aid of the Manuherikia, began filling up the excavation it had lately made in the Pliocene strata in the first headlong rush which followed its breach into the valley of the Manuherikia.

This new cycle of fluviatile deposition continued until the basin was filled up to the level of the Moutere Plains, which at this date extended across the present channel of the Clutha to the foot of the Old Man Range. Remnants of this old flood-level can still be seen in Conroy's Gully and on the rock-cut platforms between Alexandra and Bald Hill Flat.

Each river carried down and piled up the material that existed within its own drainage-area. Thus the Manuherikia contributed chiefly grauwacke. mudstones, gritstones, and conglomerates derived from the distant Hawkdun Range ; quartz and semi-angular blocks of mica schist from the adjacent schistose mountains; and masses of yellow cement-stone from the consolidated quartz-drifts of the Pliocene lignitic series, which was now subject to denudation in the middle and upper parts of the valley. The Clutha brought down semi-rounded fragments of mica schist, and well-rolled pebbles and boulders of grauwacke and black olivine basalt, the latter a rock quite foreign to the Manuherikia drainage-area. The basalt is as distinctive as it is abundant, and hence enables us with ease to trace the direction and influence of the Clutha during this constructive period. By examining the gravels in the lower end of the valley and noting the distribution of the basalt we find that the Clutha spread out its *débris* in the form of a wide fan extending from Clyde to Alexandra, and from Clyde across the Waikerikeri to a point about a mile beyond Springvale. The present Moutere Plains are a remnant of this old fan.

Some time during this period of great fluviatile activity another agency joined forces with the rivers in the process of building up and filling, and, although it has now disappeared, the tracks it left are still plainly visible. When the rivers had completed almost half their task the great glacier of the Upper Clutha crept silently down the valley and pushed its terminal face over the shoulder of the rocky spur lying across the entrance of the gorge behind Clyde. It now became an active ally of the Clutha. On its massive back it carried a load of rocky matter which it dumped down in wild disorder across the present site of Clyde. Where the heavy masses of rock fell, there they lay until piled up to a height of 400 ft.

At the toe of the moraine and at the point where the Clutha emerged from its ice-cavern the glacier drift is mingled with the water-worn sands and gravels of the river. At the 700 ft. and 900 ft. contours the Pleistocene gravels are intercalated with a layer of glacier drift extending as far as Alexandra and Springvale respectively. From this we gather that the glacier twice invaded the Manuherikia Basin for some miles, but on each occasion soon beat a retreat, scattering piles of rocky *débris* in its wake.

After the last of these advances the glacier appears to have clung tenaciously to its stronghold at Clyde until some time near the close of the Pleistocene, when it began the last great retreat, which ended in its recession to its present home among the fastnesses of the far-distant alpine mountains of the main divide. The rounded contours, flowing outlines, and *roches moutonnées* in the Dunstan Gorge above Clyde remain as mute witnesses of the great ice-invasion at this time.

With the retreat of the glacier the second cycle of deposition came to an end. The Clutha again became a destroyer, scouring out the lower end of the flood-plain it had only just laid down. In a short time it cut down its present channel and formed the terrace on which the towns of Clyde and Alexandra are built.

It is a significant circumstance that ever since the recession of the glacier the Clutha has brought down among its transported material rocks that do not appear to be represented among the gravels it brought down in Pleistocene times. In the high terrace bounding its course from Clyde to Alexandra and among the shingle of its present bed there occurs an abundance of aphanitic sandstone (melaphyre tuff), red and purple mudstones, grits and breccias, and, less abundantly, well-rounded pebbles of granite, syenite, diorite, gneiss, basalt, and monchiquite. These rocks were traced to

Cromwell, and thence along the course of the Kawarau to the moraine at Queenstown, where they are all common, with, perhaps, the exception of the olivine basalt, which may yet be traced to the valley of the Clutha. This would seem to indicate that the diversion of the Kawarau to the Clutha River took place after the recession of the glaciers at the close of the Pleistocene.

Queenstown Moraine is mainly composed of material carried by ice from the south-west side of Lake Wakatipu, and the presence of some of this material in the gravels of the middle Clutha shows the tricks that may be played by the change or diversion of a drainage system when aided by ice.

Fault Rifts.

At Lauder the Manuherikia leaves its old channel and passes abruptly through a narrow gorge cut in the schist along the flanks of Raggedy Ridge. It emerges from this rift at a point two miles above Ophir.

At Ophir Bridge the river again leaves its old course, and plunges suddenly into a deep, narrow rift in the schist, in which it runs as far as Chatto Creek, where it once more returns to its old channel.

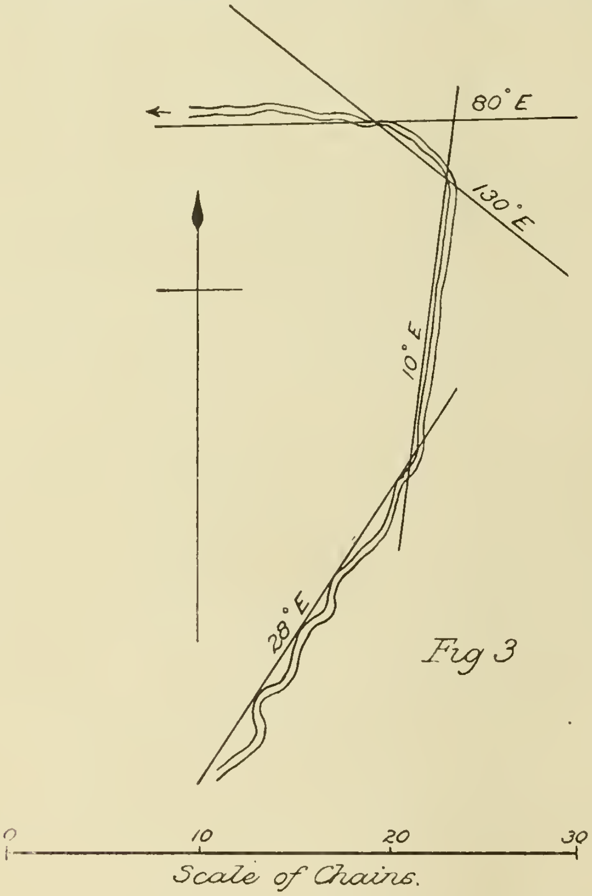
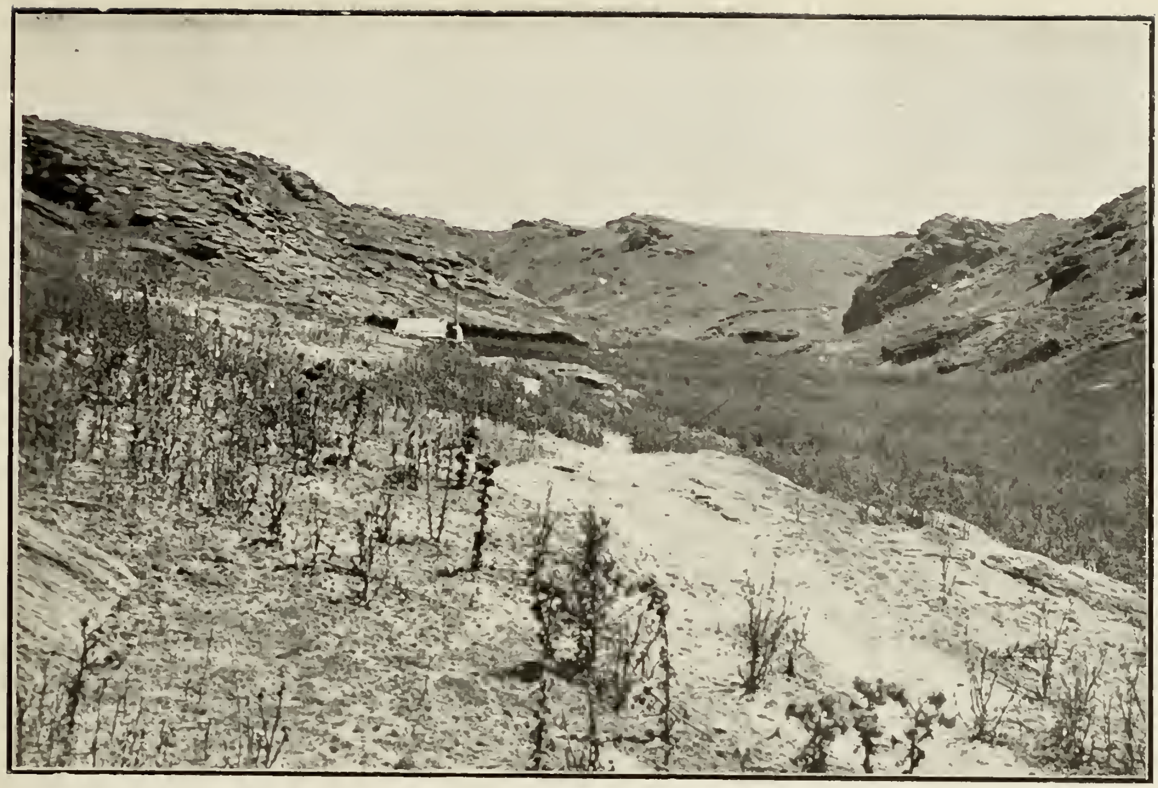
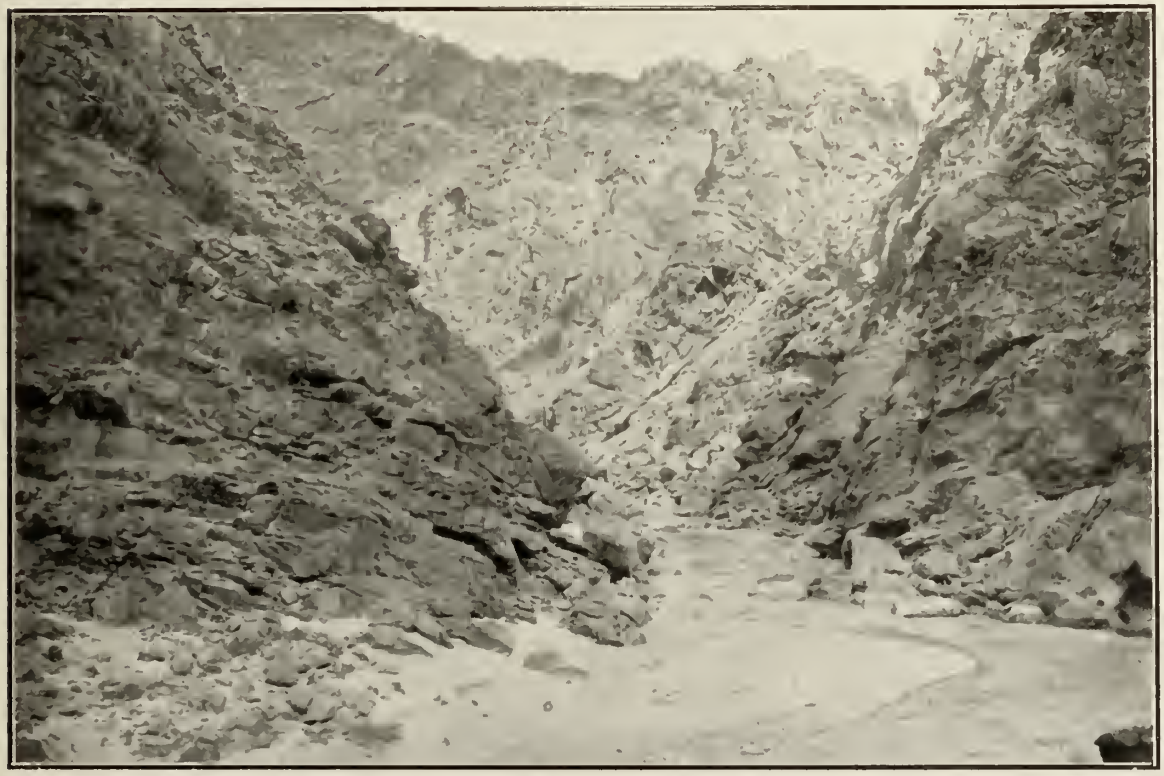


Fig. 3.—Plan showing Fault Rifts of Manuherikia River.

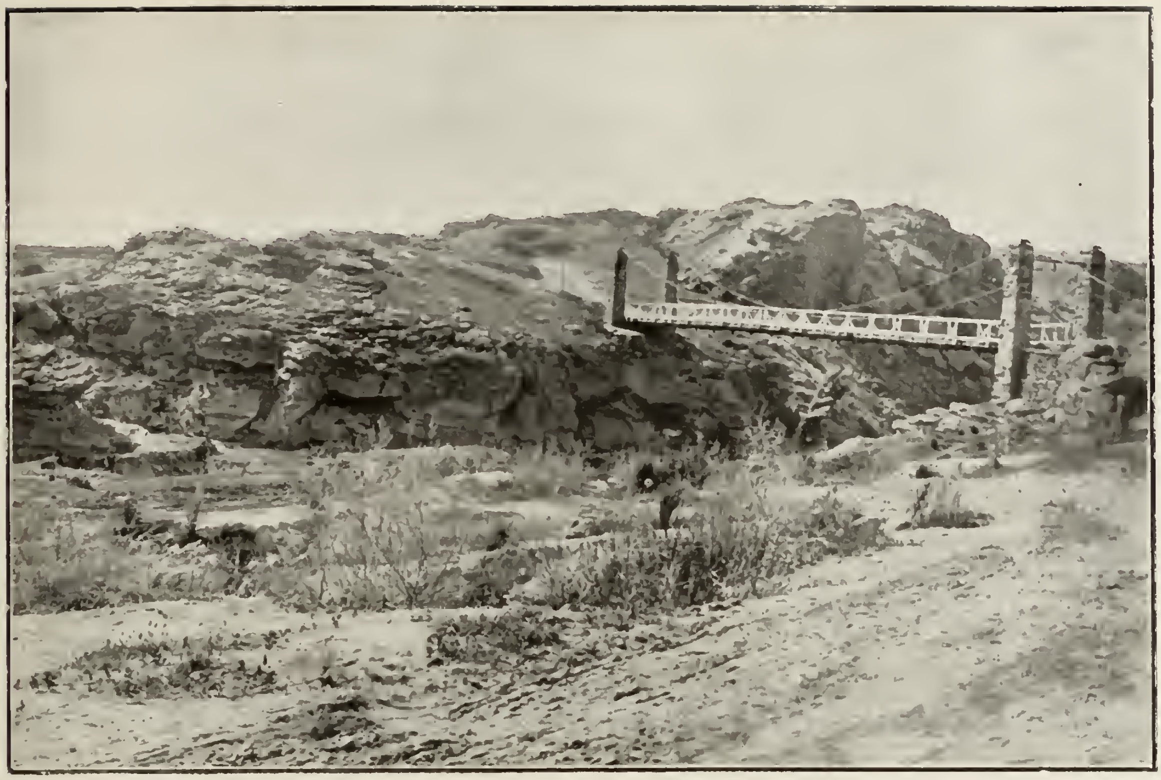
The rift is formed by a number of intersecting fault-like fractures, along which the river runs, passing from one to the other. Fig. 3 shows the course of the river from Trig. Station S to the big bend east of Chatto Railway-station, a distance of 45 chains. Both above and below this the gorge is too precipitous to permit close examination to be made.



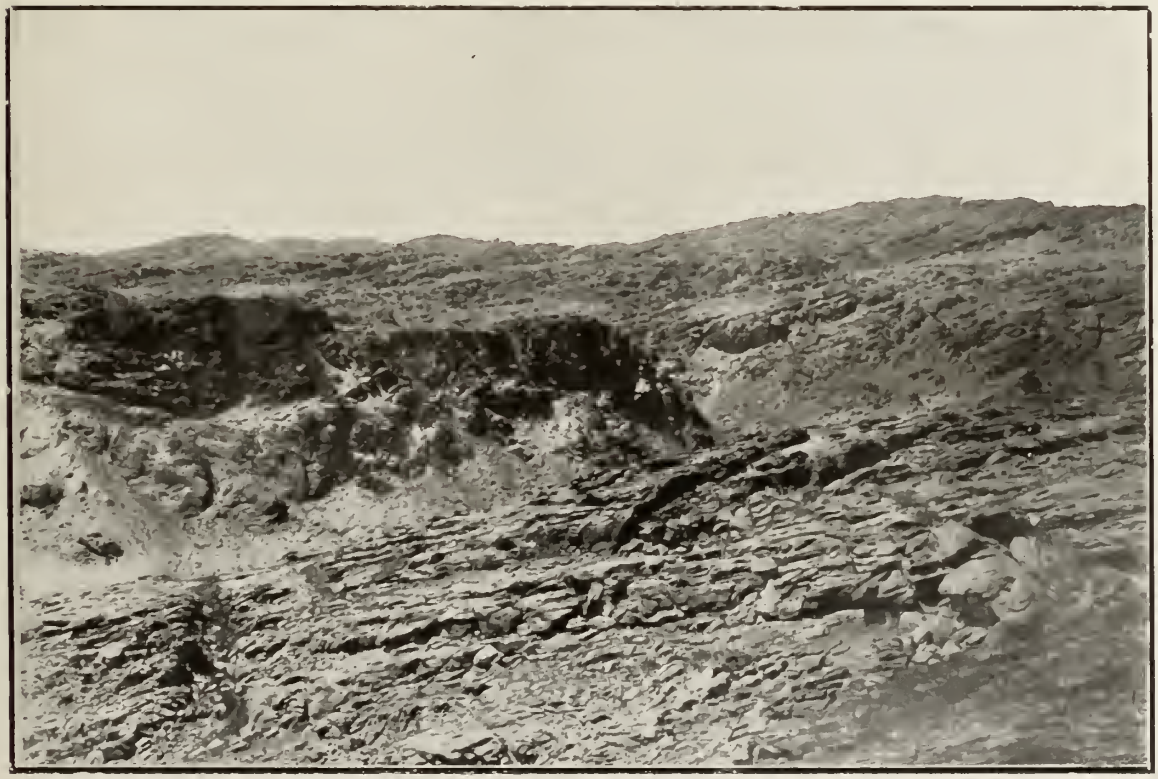
HANGING VALLEY, NOW A DRY GULLY; ONE HALF-MILE SOUTH OF ALEXANDRA SOUTH.



UPPER END OF FAULT RIFT OF MANUHERIKIA RIVER, AT OPHIR BRIDGE.



Flat-lying Mica Schist at Lower Manuherikia Bridge.



Bare Outcrop of Mica Schist near Alexandra South.

IDA VALLEY BASIN.

This basin is separated from the Manuherikia Basin by Raggedy Ridge, and lies about 300 ft. higher. It is about thirty-five miles long, and from four to eight miles wide. At the present time the south end of the basin is drained by the Poolburn Stream, and the north end by the Idaburn. These two streams unite and pass through a narrow gorge in Raggedy Ridge, the united stream joining the Manuherikia above Lauder.

Here we have singularly clear evidence of the reversal of the original drainage of the basin. The Ida Valley Basin, as shown by the river terraces and surface-contours, at one time drained into the Maniototo Basin. After the formation of the Poolburn Gorge the drainage of the upper part of the basin entered the Manuherikia, and when the gorge had been deepened the drainage of the lower end became reversed, and whereas it formerly flowed north-east it now runs south-west, as shown in Fig. 4, thus forming a typical example of an obsequent stream.

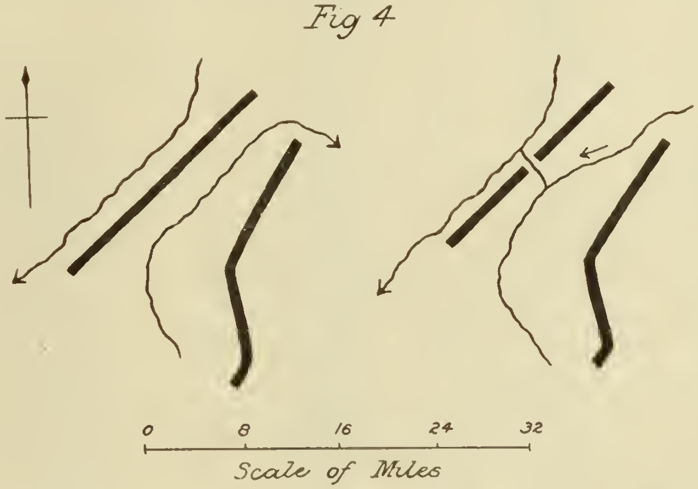


FIG. 4.—SHOWING THE DIRECTION OF THE DRAINAGE OF IDA VALLEY BEFORE AND AFTER THE CUTTING OF POOLBURN GORGE.

CHAPTER III.

GENERAL GEOLOGY.

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THE rock formations represented in this district are shown in tabulated order below in order of superposition :—

TABLE OF FORMATIONS.

Recent. River-beds, sand-hills, swamps, alluvial flats, and loess.

Pleistocene.

a. Terrace gravels and modified glacier drift, old fans.
b. Moutere terrace gravels and glacier drift.

Manuherikia series (Pliocene).

a. Siliceous cement-stones and quartz drifts.
b. Sandstone gravels.
c. Quartz sands and gravels.
d. Sands, soft sandstones and clays, with lignite.

Maniototo series (Palæozoic).

a. Mica schist, with chlorite and quartz schists.
b. Actinolite schist.

MANIOTOTO SERIES.

Actinolite Schist.

This rock is found about half a mile south-west of Ophir. It occurs as a long, narrow, dyke-like exposure in the core of a sharp anticline of chlorite schist. The exposure is about 300 yards long, and from 4 ft. to 20 ft. wide.

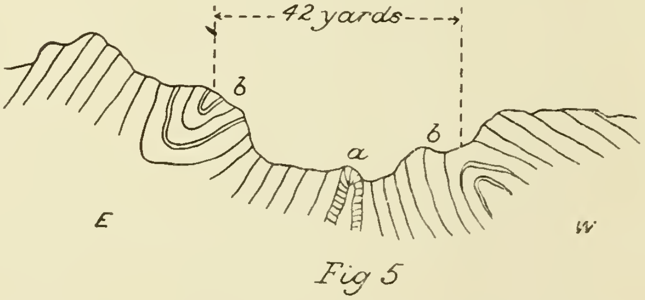

FIG. 5.—SECTION OF ACTINOLITE-SCHIST OUTCROP, LOOKING SOUTH.
a. Actinolite schist. *b.* Chlorite schist.

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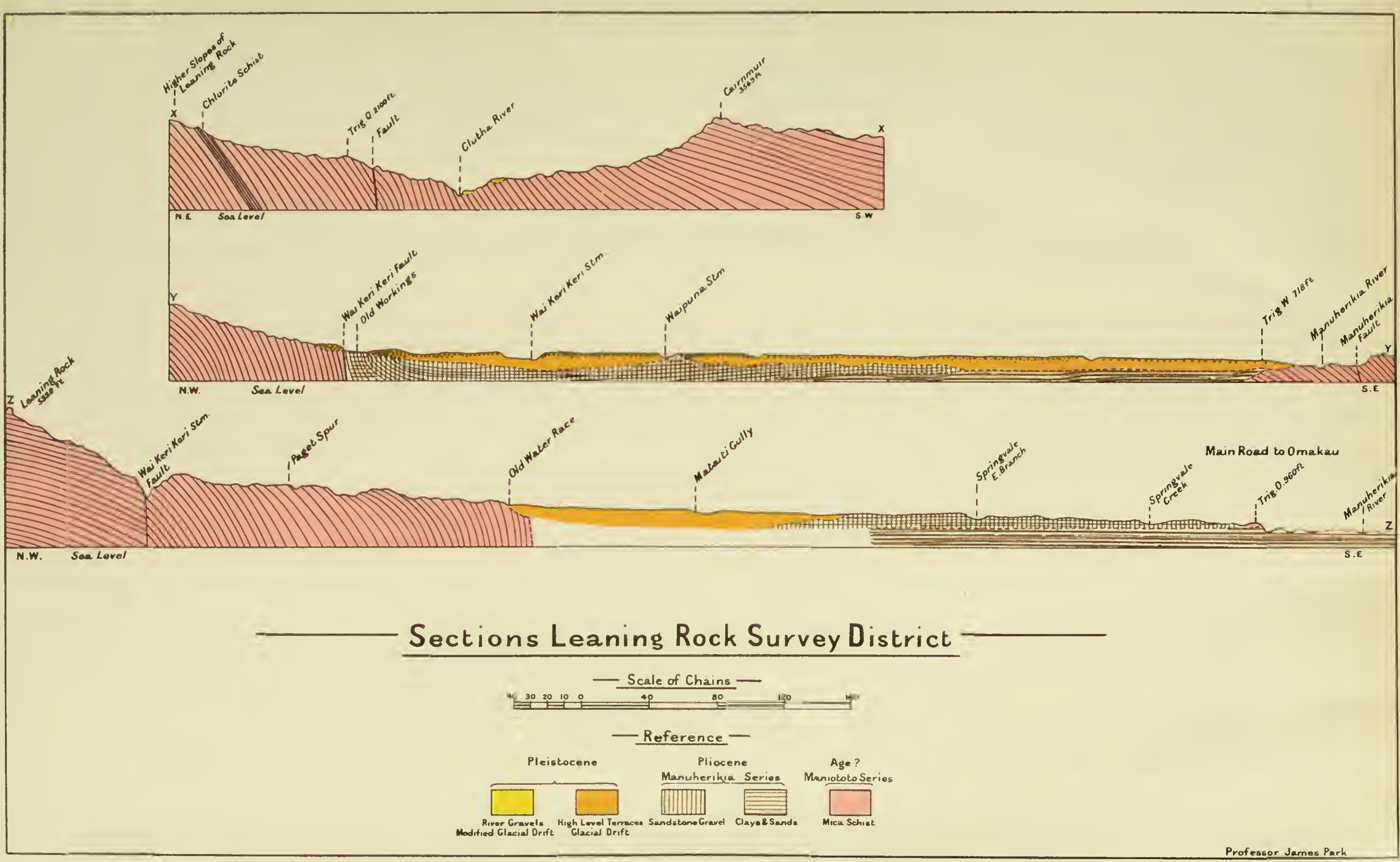

Sections Leaning Rock Survey District

Professor James Park

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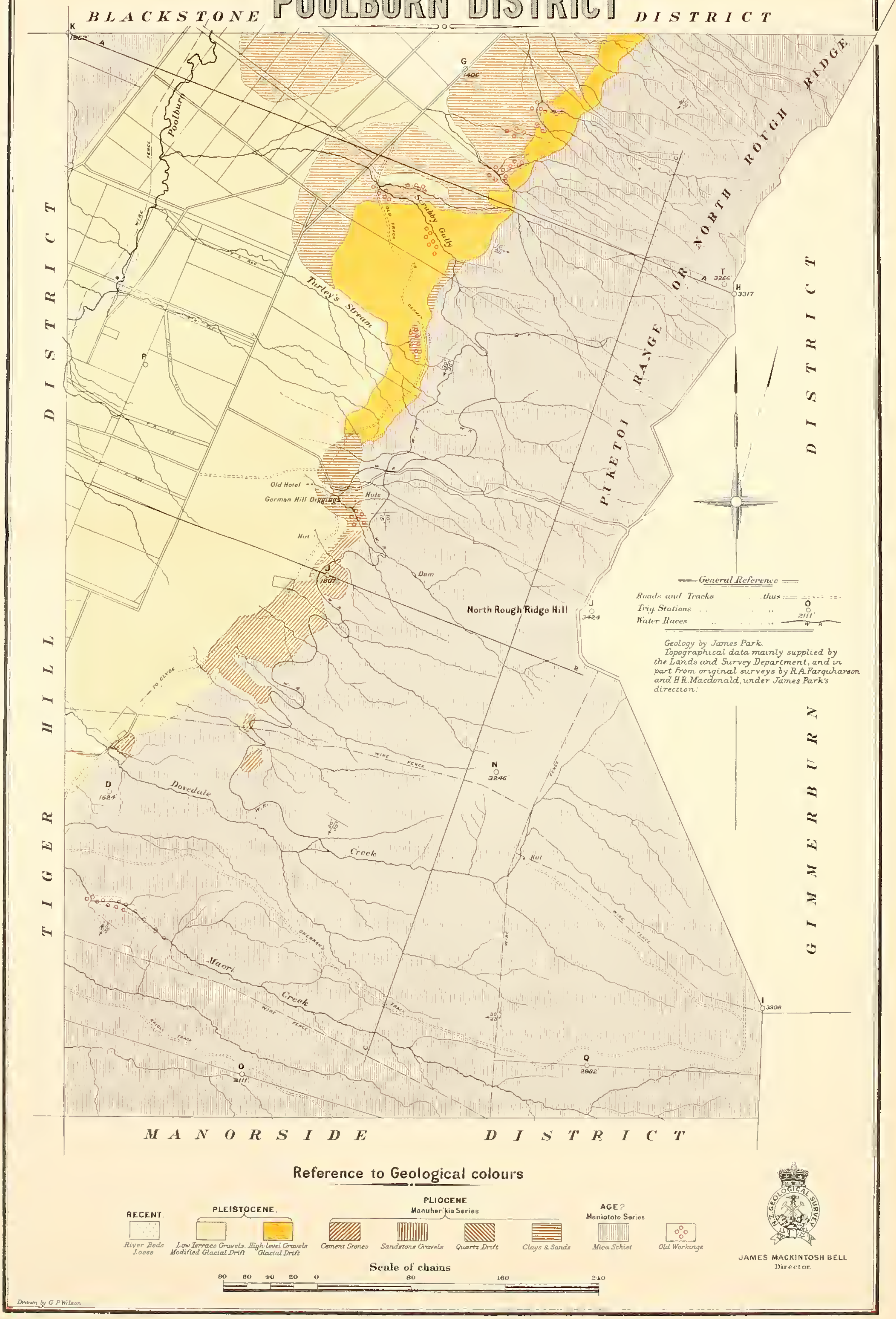
To accompany Bulletin N° 2, Alexandra Sheet, Central Otago Division

Geological Map of
POOLBURN DISTRICT



Geology by James Park.
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A.Farquharson and H.R.Macdonald, under James Park's direction.

JAMES MACKINTOSH BELL
Director.

Drawn by G P Wilson

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The actinolite schist is the lowest member of the metamorphic series exposed in this part of Central Otago. It is very compact, tough rather than hard, and, being more weather-resisting than the chlorite schist, stands up like a narrow dyke in the small depression in which it follows. Its exposure is due to the denudation of the adjacent chlorite schist, which is thrown into a sharp fold on each side. Schistose structure is but feebly developed in it.

Mica Schist.

The predominating rock of this series is a typical mica schist, well foliated with quartz laminæ. It is in most places sharply contorted. At its base there is a thick band of chlorite schist not less than 200 ft. thick, and about 2,000 ft. higher another band of chlorite schist, which is overlain by a micaceous quartz schist.

At Ophir, and at the top of Lillico's Spur leading up to the Leaning Rock, the quartz schist is grey-coloured, sometimes flaggy, but more often quite fissile. On the flanks of Leaning Rock, overlooking the Clutha at an altitude of 3,000 ft., it is pink or flesh-coloured, owing to the presence of a red-coloured mica. Thin bands of soft silvery-grey mica schist in which the quartz laminæ are like sheets of paper occur at Ophir and near the crest of Raggedy Ridge. This rock generally possesses a silky lustre and a finely corrugated structure.

The greatest thickness of the mica-schist series is found in the section running from Cairnmuir Hill to Leaning Rock, and in that along the summit of Rough Ridge from the Upper Poolburn to the north end of Rough Ridge. The most trustworthy estimate is obtained from the Cairnmuir – Leaning Rock section. Here the thickness does not exceed 10,000 ft., and is probably much less. The frequent changes of dip and strike make it difficult to calculate the thickness in the Rough Ridge section; but there is no reason to believe that the thickness exceeds 12,000 ft., or 15,000 ft. at the most.

Towards the upper part of the series the schists become insensibly less altered, and at the north end of Rough Ridge, near Wedderburn, and on the east side of the Manuherikia, near Alexandra (both places just outside the boundaries of the district under review), they pass upward into partially altered argillaceous, micaceous, and arenaceous rocks foliated with quartz, but seldom contorted or plicated. Those semi-metamorphic schists are often streaked in all directions with thin veins of quartz filling contraction cracks. Opposite Alexandra they are traversed by quartz lodes that follow the course of fault fractures. Reference to these lodes will be made further on.

Near Alexandra the upper schists contain bands of calcareous argillaceous material. These occupy the higher slopes of the foothills, and the water descending towards the river with its dissolved lime has cemented the old terrace gravels into a hard cement, which occurs in irregular sheets or layers. An attempt is about to be made at Richardson's Claim to extract the gold by crushing the cement in a stone-breaker.

MANUHERIKIA SERIES.

Sands, Soft Sandstones, and Clays, with Lignite.

This is the lowest member of the lacustrine series. It occupies the floor of the Manuherikia Basin, and is of great importance from the circumstance that it contains the seams of lignite which constitute the only form of fuel available in Central Otago.

The lignitic clays and sands are well exposed in the high cliffs on the west bank of the Manuherikia River a few miles above Alexandra, in the neighbourhood of Springvale (notably in the areas where the younger gravels have been removed by sluicing operations), in the cliffs opposite Chatto Railway-station, and at Waikerikeri Diggings. The first-named place is close to the river-ford on the road to

Galloway Flat. Here the beds dip gently to the north-west, and are traversed by a number of small step faults.

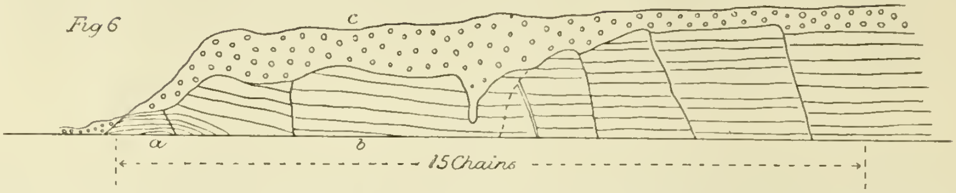

Fig. 6.—Section along West Bank of Manuherikia River near Ford on Road to Galloway Flat.
a. Tough blue clays. *b.* Alternating blue sandy clays and soft sandstones. *c.* Pleistocene gravels.

The section exposing the greatest thickness of these beds is seen in the floor of the old alluvial workings in Anderson's Creek, a small branch of Waikerikeri Stream. Here we get not only the lignite measures but the complete series of lacustrine strata standing on end, and exposed in such a way as to be easily examined.

The distribution of the lacustrine beds will be seen by a reference to Waikerikeri special map. The whole series is faulted down so as to occupy a vertical position. The clays and lignitic sands, as the lowest members of the series, abut against the mica schist, the boundary between the two formations being marked by a vertical fault. The faulting which dragged the younger series down also bent the schists into a vertical position, and it is not a little singular to see the bedding-planes of two formations so different in age and character lying parallel and coextensive.

The thickness of clays and sands seen here is 460 ft. The seams of lignite found at Dairy Creek, a mile and a half nearer Clyde, are represented in this section by a thin bed of buff or snuff-brown carbonaceous shale of a crumbling, friable character.

Sink-holes.—Practically the whole of the floor of upper Ida Valley is occupied by the clays of this series, overlain only in places by a thin skin of recent gravels. In the lower Poolburn these clays form wide plains and low terraces, and a noticeable feature of this area is the large number of sink-holes that occur wherever the clays crop out and occupy the surface. The sink-holes are shallow pans, generally from 3 ft. to 4 ft. deep, with curved outlines and irregular shape. The bottom or floor is often lined with a layer of yellow cement-stone. In the summer season these holes are dry; in the winter they are full of water, and often overflow.

Age.—The Manuherikia lacustrine series is overlain unconformably by the Pleistocene glacier drifts, and everywhere lies on a highly eroded surface of the schist. The upward age-limit of the series presents no difficulty, but the hiatus is so great on the lower side that it is impossible to say definitely whether the age should be referred to the older or newer Pliocene, or even to any part of the Pliocene.

The fossils found at or near the base of the series are Unio (two species) from Clyde and Dairy Creek, fish-remains from Cambrian's, and dicotyledonous leaf-impressions from all the coal-mines. These have not been described, and afford us little help.

Sir James Hector in 1864, and Captain Hutton in 1875, placed the lacustrine series in the Pliocene, apparently without any definite supporting evidence. In the absence, however, of any evidence that would warrant its removal to another period, I can only leave it in the Pliocene, which is probably not far wrong.

Quartz Sands and Gravels.

These follow the lignite-measures quite conformably. In the Waikerikeri section they are 138 ft. thick. They consist of clean grey quartz sands and silts, passing upward into coarser fragments that constitute what may be termed "a fine gravel of even grade." The sands are mostly sharp and angular, while the fragments composing the gravels are seldom much water-worn.

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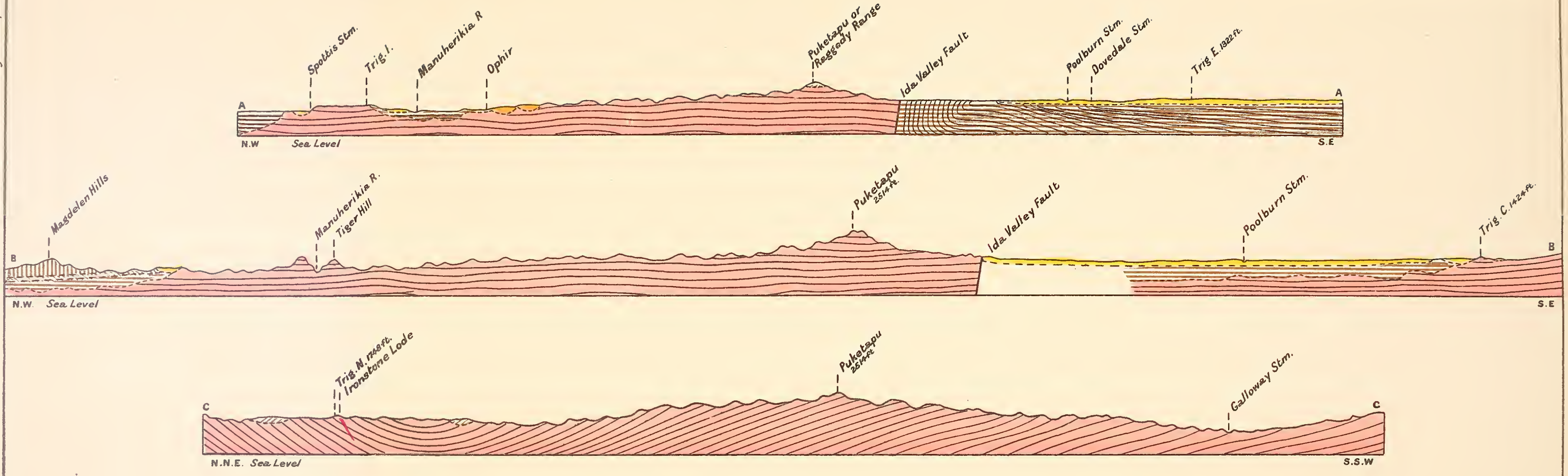

Sections Tiger Hill Survey District

Scale of Chains

40 30 20 10 0 40 80 120 160

Reference

Pleistocene

🟨 River Gravels Modified Glacial Drift

🟧 High-level Gravels Glacial Drift

Pliocene
Manuherikia Series

▨ Cement Stones

▥ Sandstone Gravels

▨ Quartz Drift

▤ Clays & Sands

Age?
Maniototo Series

🟥 Mica Schist

☐ Lodes

Professor James Park

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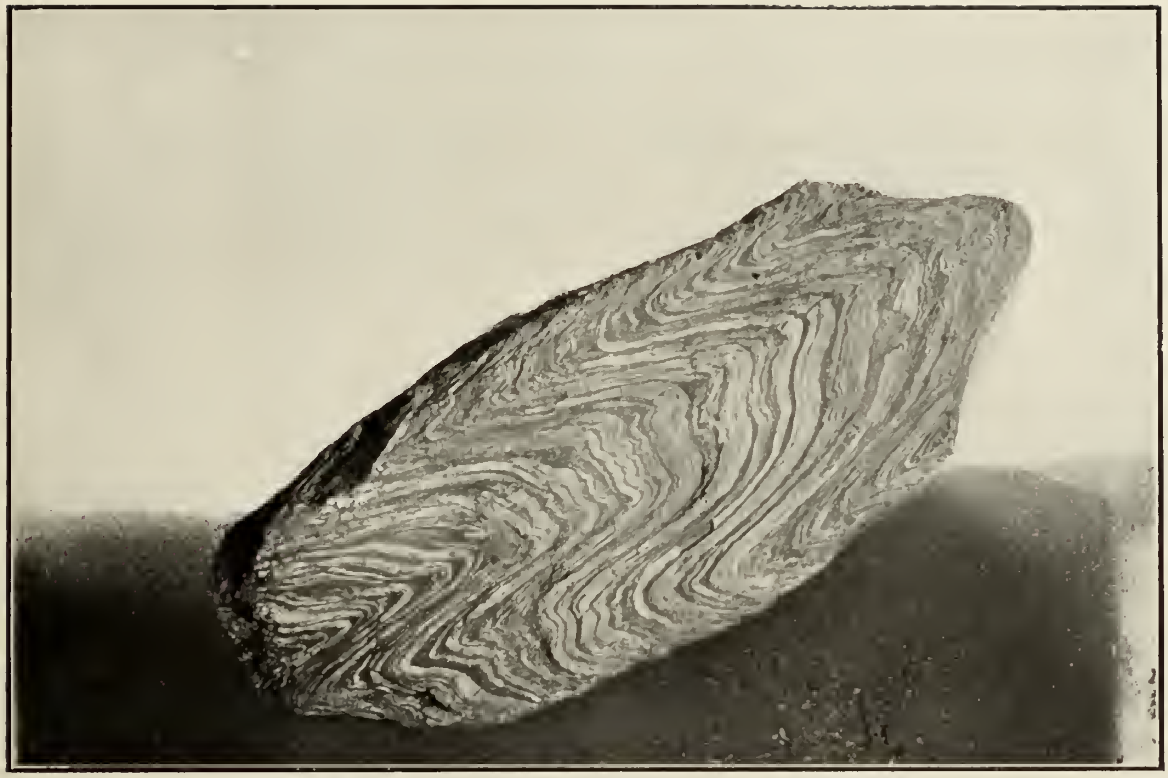
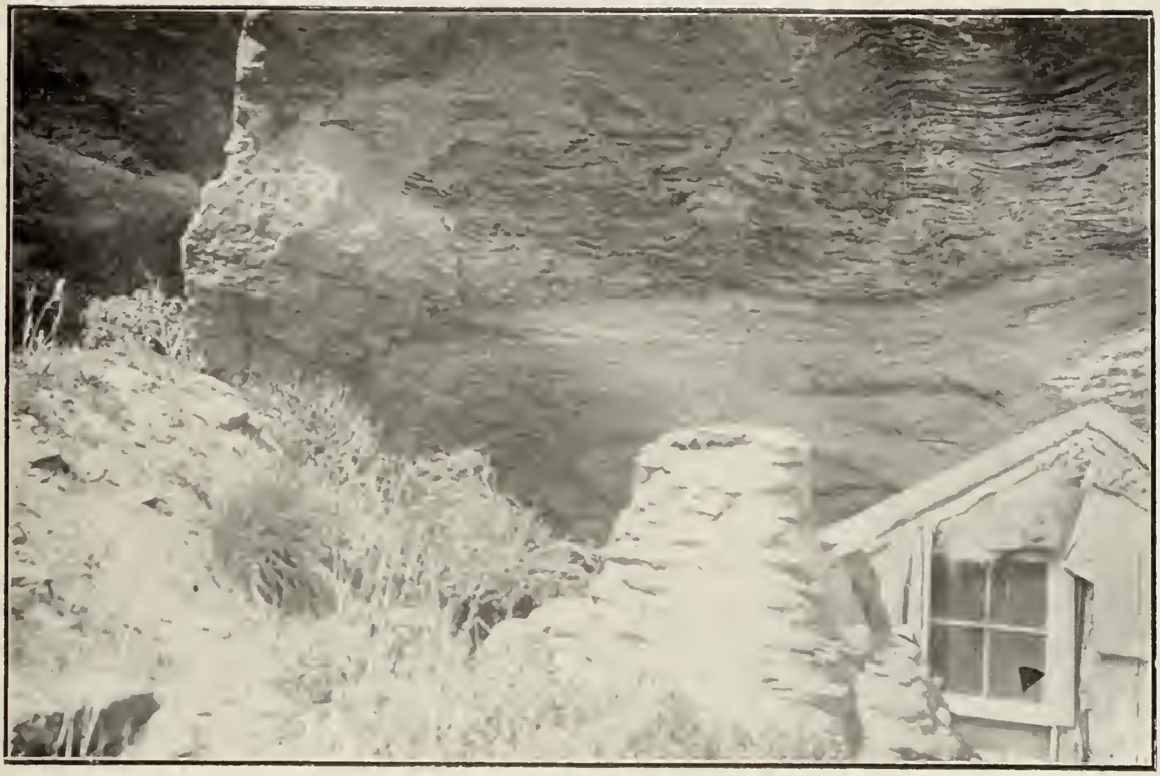
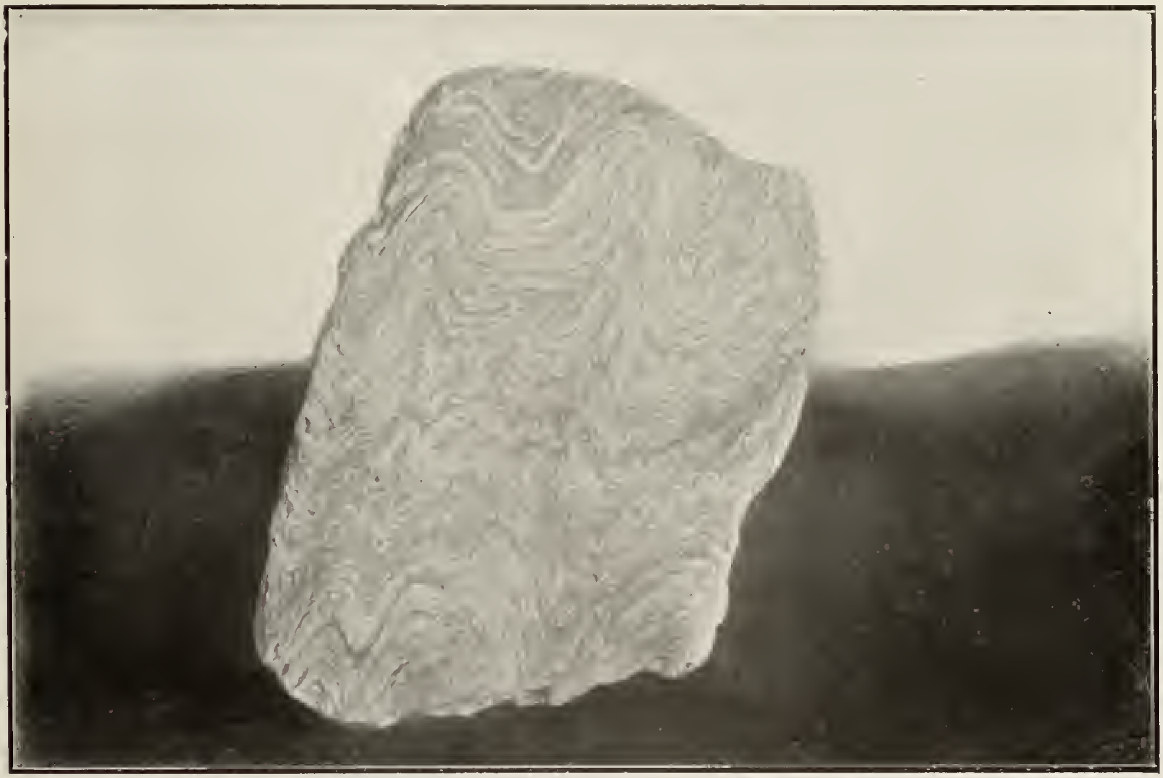


Contorted Mica Schist.



Contorted Mica Schist, East Side of Manuherikia, near Alexandra South.



Sharply-contorted Mica Schist.

Scale : 1 in. = 6 inches.

The quartz of these drifts has manifestly not travelled far. It was, no doubt, derived from the denudation of the mica schist in the immediate vicinity. These quartzose beds are gold-bearing, and throughout Central Otago are known to alluvial miners as "granite wash" or "granite bottom."

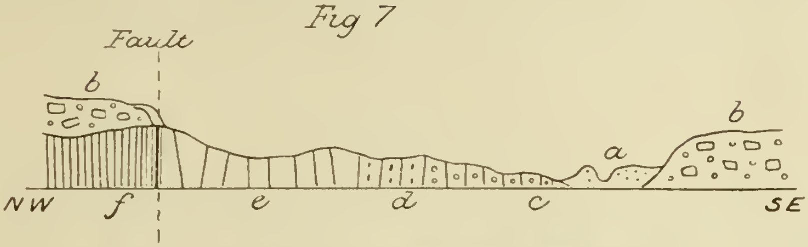


Fig. 7.—Section of Lacustrine Beds at Waikerikeri.
a. Rewash gravels. *b.* Morainic drift. *c.* Sandstone gravels. *d.* Quartz sands and gravels. *e.* Clays an sands. *f.* Mica schist.

Sandstone Gravels.

These consist of yellowish-brown sandstone gravels that stand on edge and follow the quartz drifts conformably. The visible thickness is 335 ft. The total thickness may be much greater, but cannot be determined on account of the overlying gravels of more recent date.

The gravels are composed of well-rounded pebbles of grauwacke and quartz, seldom over 6 in. in diameter, mixed with sandy material. The upper 100 ft. are more sandy and quartzose than the lower portion. The grauwacke is a rock foreign to the district. It is found *in situ* in the Hawkdun Mountains, at the sources of the Manuherikia River, which was the agency that transported it to this place.

These lacustrine gravels are the upper or closing member of the Manuherikia series. They are overlain unconformably by the Pleistocene glacier drifts and gravels. The relationship existing between the lacustrine gravels and the Pleistocene drifts is well seen in the face of the old alluvial workings on the north side of Anderson's Creek, immediately north of the tailings-heap marked on the special map.

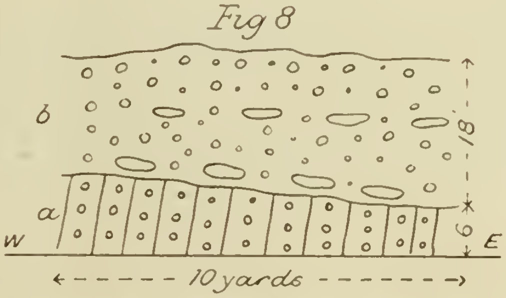


Fig. 8.—Section showing Uncomformity between Pleistocene Drifts and Lacustrine Gravels.
a. Lacustrine gravels. *b.* Pleistocene drifts.

In bare cliffs and river-banks wherever clear exposures are to be found there is no difficulty in distinguishing the Pliocene sandstone gravels from the overlying Pleistocene drifts. The former, as we have seen, consist chiefly of round pebbles of grauwacke, fairly uniform in size, and pebbles of quartz, not so abundant. Aphanite sandstone is represented, but is not common.

The Pleistocene drifts, besides grauwacke (which predominates) and quartz, also contain an abundance of mica schist, generally in angular or partially water-worn pieces, large yellowish-grey cement-stones, and boulders of olivine basalt. The mica schist, cement-stones, and basalt are thus the distinguishing constituents of the Pleistocene drifts. The two former are present everywhere. The basalt is found only in the drifts in the lower end of the Manuherikia Valley, in the fan-shaped area radiating from Clyde and formerly subject to the influence of the Clutha River.

On grassy slopes covered with soil it is not easy accurately to define the limits of the Pliocene and Pleistocene gravels.

Siliceous Cement-stones.

These consist of quartz sands and gravels that have been cemented into a compact stone by the infiltration of siliceous waters. They are found *in situ* at German Hill (on the east side of Ida Valley), at Rough Ridge, Chatto Creek, and Galloway Run, near the Manorburn.

The cement-stones are known to the miners as "Chinamen." As scattered boulders they are found in the Pleistocene and later drifts throughout all the old lake-basins. They also occur abundantly on Galloway Run, and around the flanks of Raggedy Ridge and Rough Ridge, resting directly on the mica schist, in some places at an elevation 1,800 ft. above sea-level.

The sheet of cement-stone at Chatto Creek varies from 4 ft. to 6 ft. thick. It is interbedded with the lacustrine series, and is simply a stratum of the quartzose drifts which sometimes occur near the base of the series cemented into a hard siliceous stone. Its position is shown in the following diagram :—

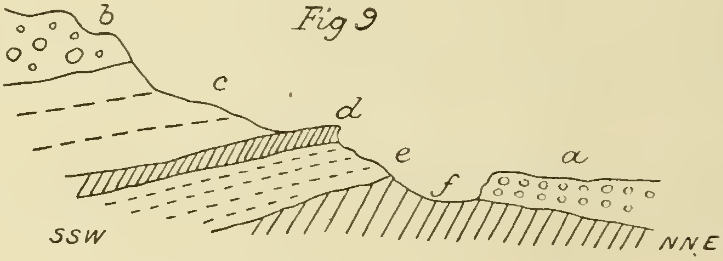


Fig 9.—Section near Mouth of Chatto Creek.

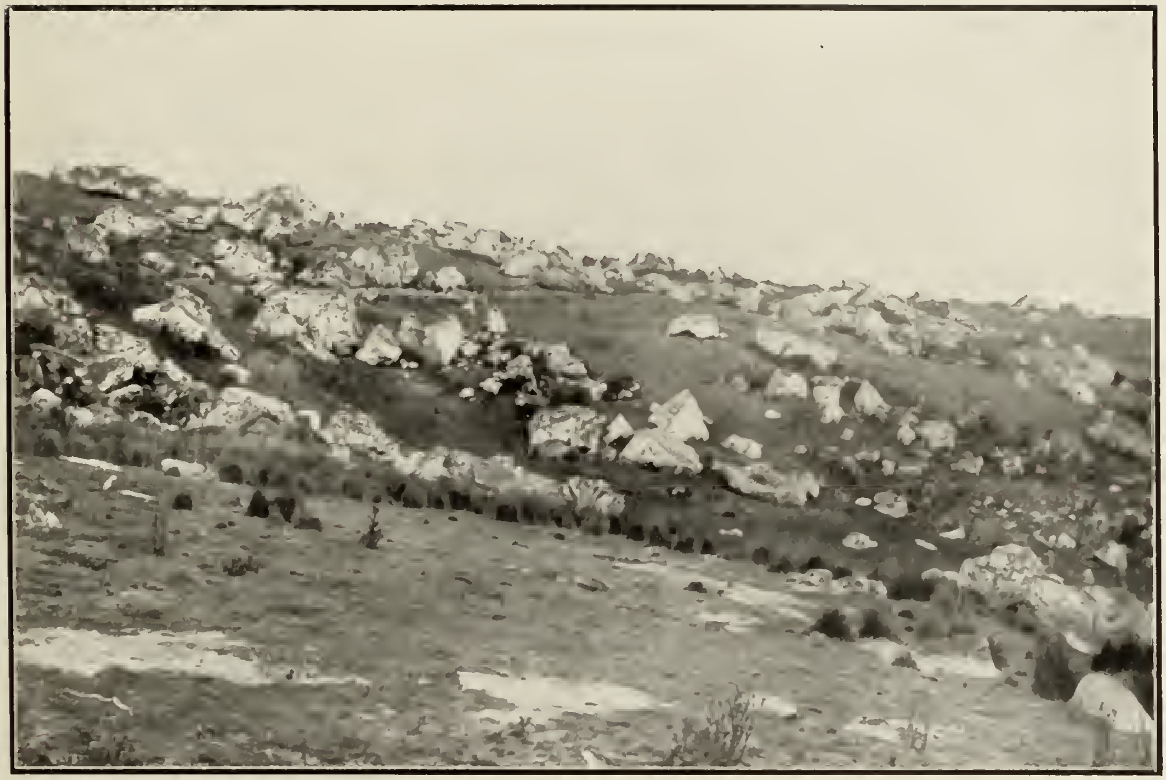
a. Terrace gravels. *b.* Gravels of old fan, 15 ft. *c.* Fine greasy silts and stiff blue clays. *d.* Stratum of cement-stone. *e.* Grey quartz sands and grits. *f.* Mica schist decomposing into soft talcose clays mixed with small angular fragments of quartz.

In this stratum of cement-stone there are thin irregular streaks of banded chalcedonic quartz similar to that deposited by the thermal springs at Rotorua and Rotomahana.

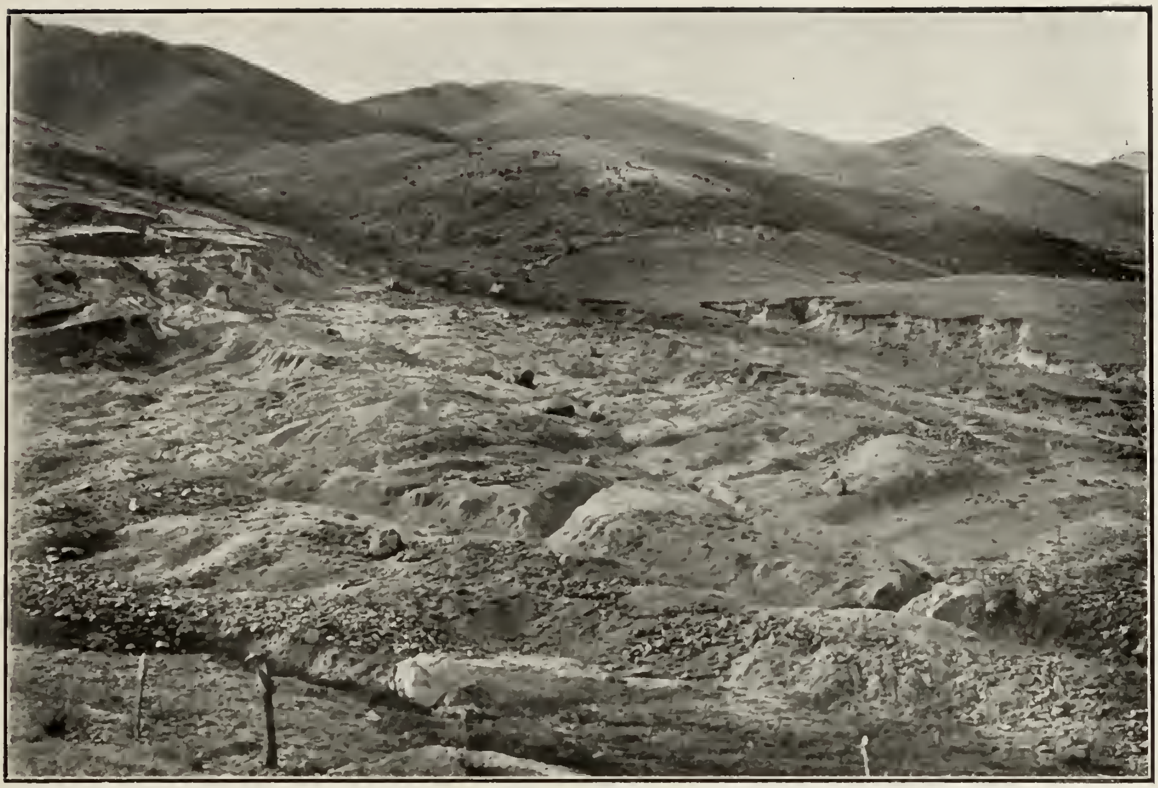
The Chatto Creek cement-stone deposit occurs at an altitude of some 600 ft. above sea-level, in such a position as to make it improbable that it was the source of the cement-stones found in the Pleistocene drifts which crown the surrounding hills at a height of 1,200 ft. above the sea.

The greatest deposit of cement-stone is that at German Hill, in Ida Valley. It covers an area exceeding a square mile in extent. The upper edge rests directly on the mica schist, the lower on a deposit of quartzose drift that is gold-bearing. The sheet was at one time continuous, but it now consists of huge tabular masses, often 100 ft. long, 20 ft. wide, and 12 ft. thick, lying on the schist like great fallen monoliths.

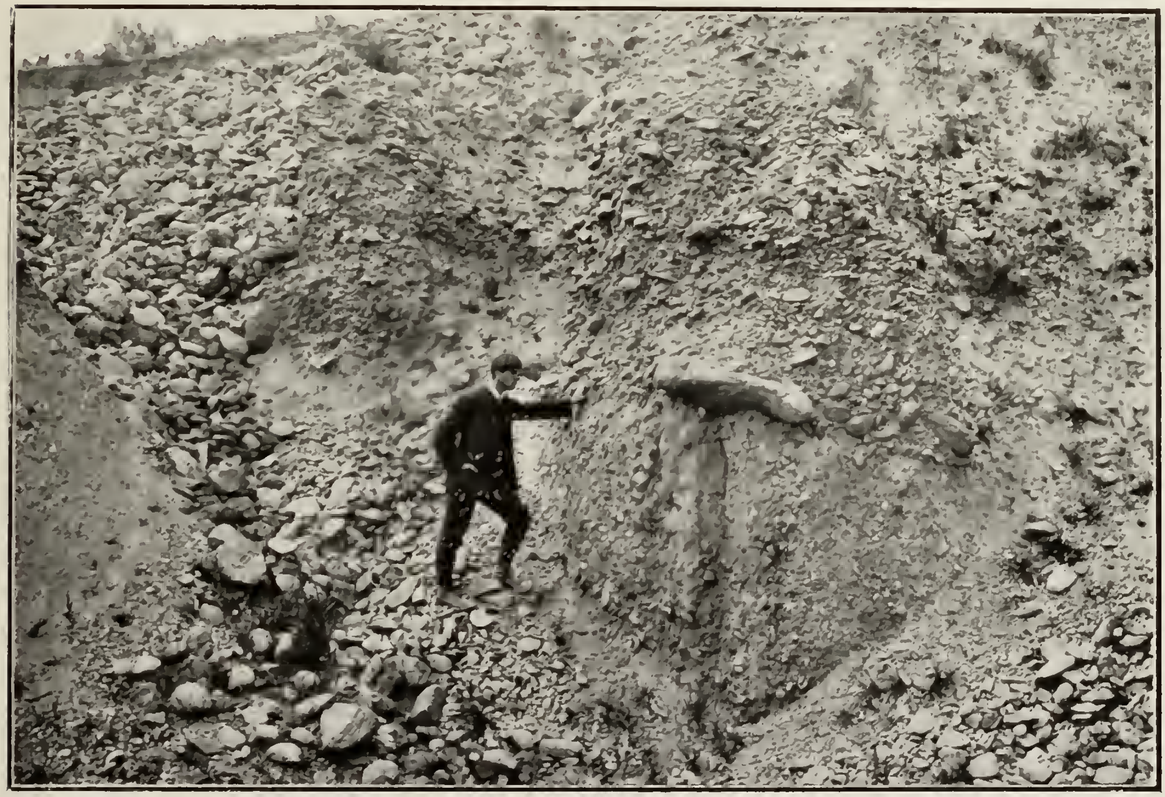
Patches of cement-stone are numerous on Galloway Run in the area enclosed by the Crawford Hills, Manorburn, and Galloway Creek. Some of those near the homestead are very coarse in texture, and rusty-brown and cindery in appearance, being cemented partly by infiltrated silica and partly by iron-peroxide. In places they rest directly on the mica schist ; in other places on a deposit of rubbly angular quartz, often mixed with coloured clays.



Grey Siliceous Cement-stone, German Hills, Ida Valley.



Waikerikeri Goldfield.



Unconformity between Vertical Lacustrine Beds and Morainic Pleistocene Gravels, Waikerikeri Goldfield.

The deposits of cement-stone in the Manuherikia and Ida Valleys appear to follow the high-level shore-line of the old lakes that at one time filled these basins. but there is no evidence to show that they at any time formed a continuous sheet. The present distribution of the cement-stones favours the opinion that they occurred as isolated deposits of a local character.

The cementing medium is silica, deposited from siliceous waters which probably had some genetic relation to the great lines of fault fracture that traverse the margins of the old lake-basins to which reference has already been made. Hydrothermal action along lines of faulting is not uncommon in different parts of the globe.

PLEISTOCENE.

Moutere Gravels and Glacier Drift.

These are chiefly developed in the area extending from Clyde to the Upper Waikerikeri, and from Alexandra to near Chatto Creek and Galloway Flat. Along the base of the Dunstan Range the gravel drifts of this age are mingled with glacier drift. Mr. McKay* refers to the presence of morainic material at Waikerikeri, but, curiously enough, both this writer and Captain Hutton seem to have overlooked the great moraine immediately behind Clyde.

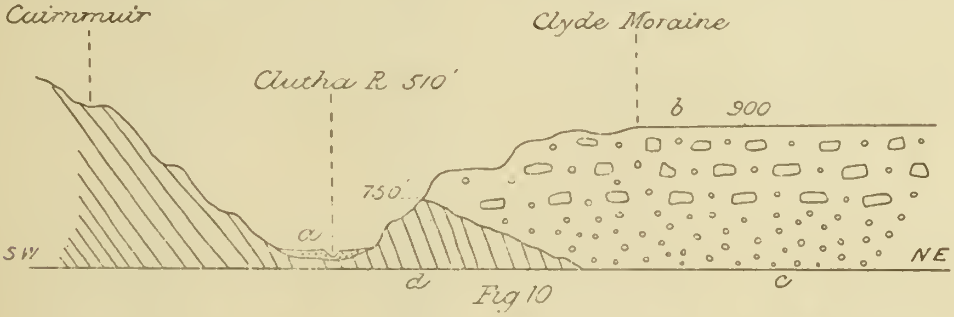


FIG. 10.—SECTION ACROSS CLUTHA AT CLYDE, SHOWING POSITION OF GREAT MORAINE.
a. River terrace. *b.* Moraine. *c.* Pleistocene gravels. *d.* Mica schist.

The moraine at Clyde is composed of tumbled masses of mica and quartz schist mixed with clay and water-worn pebbles of grauwacke, quartz, and olivine basalt.

The Pleistocene gravels in the terrace behind Clyde are free from glacier *débris* up to the 750 ft. contour-line. The greatest thickness of morainic matter is 400 ft.

A detailed description of the Galloway terraces and the Bonanza Claim was supplied by the author to the Geological Department in 1888.†

Modified Glacier Drift, Terrace Gravels, and Old Fans.

The terrace on which Clyde is built is composed of river gravels mixed with glacier *débris* derived from the erosion of Clyde Moraine. This modified glacier drift does not extend far below Mutton Town Gully. The terrace stretches down to Alexandra, but is composed almost entirely of sands and gravels brought down by the Clutha.

Besides grauwacke, gritstones, and occasional masses of silicified wood, there now appear in the terrace gravels well-rounded boulders of green, purple, and red sandstones, gritstones, and breccias, small pebbles of granite, syenite, diorite, monchiquite, and porphyrite. The red and green sandstones are brought down by the Clutha from the Wanaka country, and the granites, syenites, and other igneous rocks by the Kawarau from the Shotover and the old glacier moraines on the shores of Lake Wakatipu.

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* A. McKay, "The Older Auriferous Drifts of Central Otago," Wellington, 1897, p. 46.

† J. Park, Geol. Reports and Explorations, 1888–89, pp. 22–24.

The terraces bounding the Clutha between Clyde and Alexandra are gold-bearing. They have been the source of a large proportion of the gold won in Central Otago during the past forty years.

Recent.

Under this head are included river-beds, low-lying river-flats subject to inundation during high floods, drifting sand, and loess.

The drifting sands seen on the Clyde side of Alexandra are derived from the high terrace behind the cemetery. They descend from a funnel-shaped gully half a mile past the cemetery, and form a steeply inclined fan at the foot of the terrace, whence they are carried by the wind over the surrounding ground in a thin layer seldom more than 4 ft. or 6 ft. thick.

Moa-bones are not uncommon in the sand-formed fan, but they are generally broken and in a bad state of preservation. In the loess on the bank of the Clutha near Alexandra there was found in 1898 a moa's egg, the only perfect example in existence. A detailed description of the conditions under which the egg was found is given in a paper read before the Otago Institute, in 1900, by Professor Benham,* of Otago University.

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* Benham, Trans. N.Z. Inst., vol. xxxiv, 1901, p. 149; and A. B. Meyer, "On the Eggs of the Moa," *Ibis* 1903, p. 188; and Benham, *loc. cit.*, 1903, p. 632.

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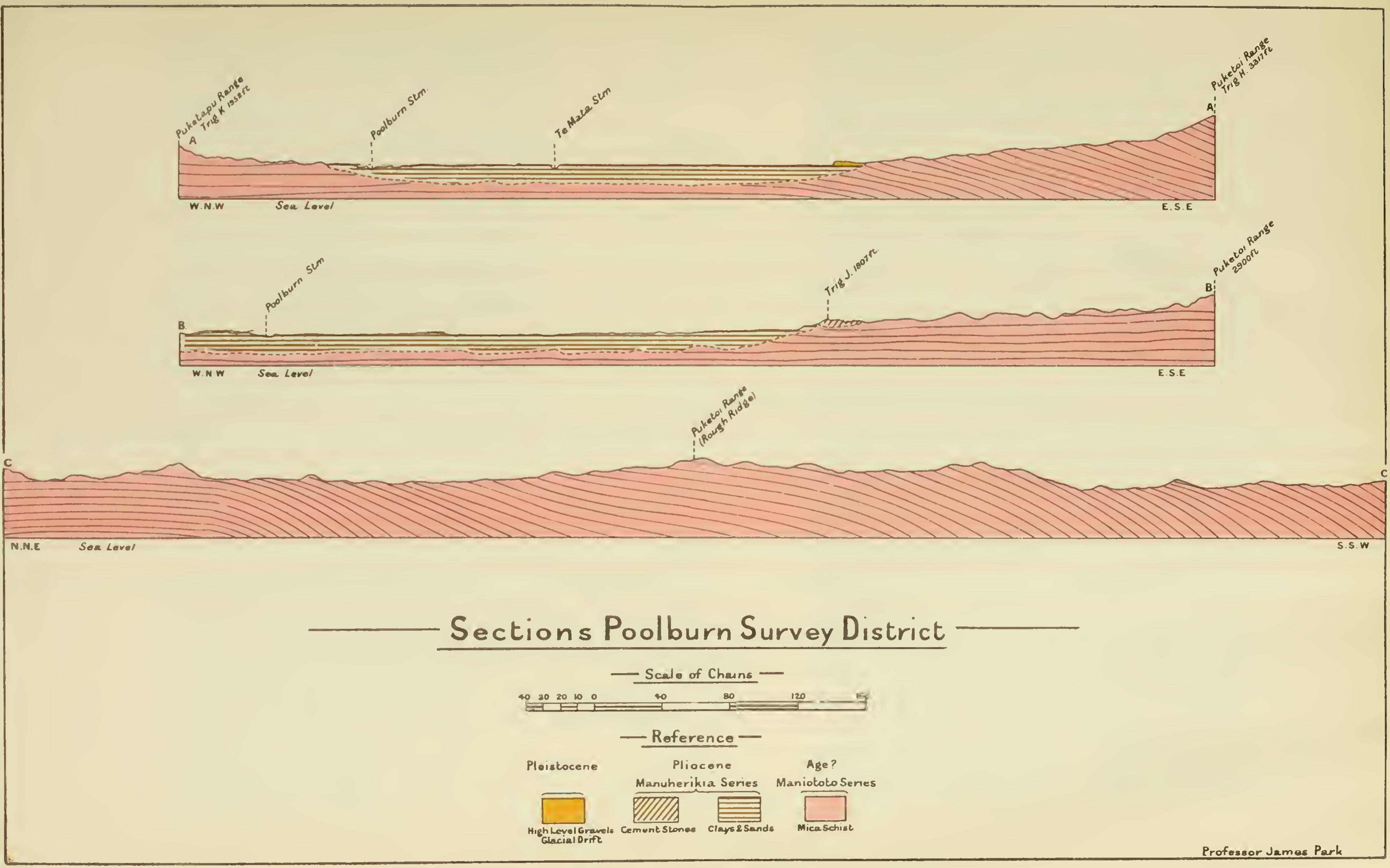

Sections Poolburn Survey District

Professor James Park

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Clyde, with Great Moraine in the Background.

Great Moraine behind Clyde.

CHAPTER IV.

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GOLD.

Historical.

THE earliest recorded discovery of gold in Otago was made in 1851, by Mr. C. J. Pharazyn and Mr. C. J. Nairn, two Wellington runholders who were on the search for grazing-country in Otago and Southland. In a letter to Captain Cargill, written at Goodwood, and dated the 27th October, 1851, these early colonists reported the discovery of both gold-bearing quartz and alluvial gold on the estate of Mr. Charles Suisted, at Goodwood.

In 1856 Mr. Charles Ligar, at that time Surveyor-General for New Zealand, reported to the Hon. the Superintendent of Otago the discovery of gold in the gravel and sand of the Mataura River, at Tuturau. He expressed the opinion that a remunerative goldfield existed in the neighbourhood.

In 1857 a petition signed by 138 inhabitants of the Province of Otago was presented to the Provincial Council, setting out that, the existence of gold in the province being a well-ascertained fact, a handsome reward should be offered for the discovery of a remunerative goldfield. The petitioners were successful, and a sum of £500 was voted as a bonus for the discovery of a remunerative goldfield within the Province of Otago.

In a report dated the 2nd June, 1857, Mr. J. T. Thomson, Chief Surveyor for the province, states that not only was gold to be found at Tuturau, but that he was credibly informed that indications were everywhere met with in the Waihopai and Mataura Plains.

The first intimation of the presence of gold in the Manuherikia Basin is contained in a report by Mr. Alexander Garvie, Assistant Surveyor, dated the 15th July, 1858. In this report he says that "the eastern portion—from the coast to Manuherikia—appears to be composed almost entirely of rocks belonging to the mica-schist system. Towards the south-west clay slate and altered rock appear, as at Tapanui, the lower part of the Pomahaka, and the Clutha below the Tuapeka. . . . Traces of gold were found in the gravel of several of the streams and rivers. The trials were all made on the very surface, at such odd times as would not interrupt the proper work of the survey, by one of the party who happened to have previously visited the Australian goldfields. The gold was in every case small and scaly, varying from the smallest specks to about the roughness of bran. It was found in the Clutha above the junction of the Manuherikia, and in the Tuapeka Stream, in sufficient quantities to make it probable that it would pay to work if set about in a proper manner with some wholesale system of washing, such as sluicing. Specks were also found in the Manuherikia, Pomahaka, and Waitahuna, and it will probably be found also in some of the tributaries of the Mataura."*

In a footnote appended to Garvie's report Mr. J. T. Thomson stated that the best sample of gold yet brought into town was found in the Tokomairiro River, south branch. The locality referred to is Woolshed Gully, where a miner named Edward Peters, otherwise "Black Peter," a native of Bombay, obtained small quantities of gold from the sands of the river by washing.

In 1858 Mr. Thomson discovered gold in the Lindis River. In the same year a little gold was found in the Kuri Stream, which flows into the sea near Hampden.

Early in 1861 some coarse gold was discovered by Samuel McIntyre in the Upper Lindis Gorge, on the north side of Lindis Peak. On the 4th June of the same year, in a letter to Major Richardson, Thomas Gabriel Read reported the discovery of gold in the ravines and tributaries of the Tuapeka and Waitahuna. He states that at many places he found prospects which would hold out a certainty that men with proper tools would be magnificently rewarded. In one place, working for ten hours with pan and butcher's knife, he collected about 7 oz. of gold.

The discoveries of Gabriel Read completely eclipsed all others, and soon led to a large output of gold. The valley in which Read made his famous discovery was named Gabriel's Gully, and as such is known to this day. The production of so much gold gave an immense impetus to agricultural and pastoral pursuits throughout Otago, and was followed by a period of great prosperity and a large increase of population.

Soon after the discovery of Gabriel's Gully gold was found in payable quantities at Wetherstones, Maraewhenua, and other places in Tuapeka County.

In August, 1862, Hartley and Riley—the first a native-born American, the latter an American Irishman—made their far-famed discovery of gold in the Dunstan Gorge of the Clutha River, about a mile below the junction of the Kawarau. In the same month Stebbing discovered very rich gold at the junction of the Clutha and Manuherikia, where Alexandra is now situated. This was the first discovery of a payable goldfield in the Manuherikia Basin. In a few months the country was swarming with prospectors, and discovery after discovery followed in rapid succession.

In October, 1862, Mr. Vincent Pyke, at that time Commissioner of Goldfields, reported that a party of miners had been found working on the Dunstan Stream near its junction with the Manuherikia. These workings were at first called Welshman's Gully, but are now known as Cambrian's.

Then followed the discovery of Conroy's Gully (so named after its discoverer), which proved to be one of the richest of the early finds. Butcher's and Blackman's Gullies, heading back to the Old Man Range, and lying to the north and south of Conroy's respectively, were next opened up. Drybread and Tinker's, on the eastern slopes of the Dunstan Range, were discovered early in 1863, and many other small fields of less note.

In April, 1864, rich gold was discovered near Black's station homestead, on the present site of Ophir.

Production of Gold.

The gold exported from Dunedin in 1861 amounted to 187,695 oz.; in 1862, to 397,601 oz; and in 1863, to 601,710 oz. Thereafter there was a gradual decrease in the production, until in 1876 the gold entered for export at H.M. Customs amounted to only 108,953 oz.

How much of the gold produced in these years should be credited to that portion of Central Otago contained in Vincent County is unknown, as the books of the Customs Department do not distinguish the output of the different goldfields.

Since 1877 up till the end of March, 1906, the gold produced in Vincent County amounts to 875,958 oz. It is almost certain that the total output of the county exceeds 1,000,000 oz., representing a value of about £4,000,000 sterling.

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* *Otago Provincial Gazette*, September, 1858.

The following interesting tables, prepared for me by the courtesy of Mr. C. W. Chamberlain, Collector of Customs, show the gold-production of Otago from 1861 to 1876, and of Vincent County from 1877 to the end of March, 1906 :—

TABLE I.—GOLD EXPORTED (SHOWN IN H.M. CUSTOMS BOOKS AS NEW ZEALAND PRODUCE, BUT IS PROBABLY ALL OTAGO).

	Oz.	dwt.	gr.		Oz.	dwt.	gr.
1861 (Aug.–Dec.)	187,695	9	6	1866	162,467	11	0
1862	397,601	8	0	1867 (January–June)	79,761	0	0
1863	601,710	15	0				
1864	427,184	0	1		2,110,116	13	7
1865	253,696	10	0				

TABLE II.—GOLD EXPORTED FROM OTAGO (1867 TO 1876).

	Oz.	dwt.	gr.		Oz.	dwt.	gr.
1867 (June–Dec.)	69,587	10	12	1874	130,743	15	18
1868	163,088	14	21	1875	115,441	17	10
1869	150,567	6	13	1876	108,953	4	18
1870	162,694	13	18				
1871	150,651	17	1		1,382,867	2	10
1872	152,324	14	19				
1873	178,813	7	0				

TABLE III.—RETURN OF GOLD EXPORTED FROM OTAGO IN YEARS FROM 1877 TO 31ST MARCH, 1906.

	Oz.	dwt.	gr.		Oz.	dwt.	gr.
1877	105,082	1	10	1894	70,259	8	6
1878	97,387	19	12	1895	80,318	15	20
1879	92,850	4	3	1896	79,344	2	9
1880	103,982	2	7	1897	65,279	17	11
1881	89,261	11	7	1898	45,557	10	18
1882	71,902	5	1	1899	126,864	13	13
1883	78,634	0	13	1900	120,167	8	11
1884	71,196	11	10	1901	133,503	13	11
1885	67,043	4	21	1902	172,336	0	22
1886	73,858	9	1	1903	156,614	12	16
1887	62,626	6	2	1904	156,875	11	3
1888	65,796	3	9	1905	153,362	15	12
1889	59,909	4	15	1906 (March quarter)	29,051	17	12
1890	58,818	4	19				
1891	83,604	7	4		2,722,930	14	2
1892	78,780	18	5				
1893	72,660	12	11				

TABLE IV.—TOTAL GOLD EXPORTED FROM OTAGO.

	Oz.	dwt.	gr.
August, 1861, to June, 1867	2,110,116	13	7
June, 1867, to end of 1876	1,382,867	2	10
January, 1877, to March, 1906	2,722,930	14	2
	6,215,914	9	19

TABLE V.—GOLD EXPORTED FROM VINCENT.

	Oz.	dwt.	gr.		Oz.	dwt.	gr.
1877	30,416	12	14	1894	17,095	17	18
1878	27,412	4	9	1895	21,907	6	18
1879	29,420	5	21	1896	22,740	13	4
1880	27,278	13	6	1897	24,764	3	4
1881	24,977	16	23	1898	14,431	16	18
1882	20,657	7	2	1899	40,034	16	5
1883	23,059	12	19	1900	57,779	10	14
1884	20,402	2	18	1901	61,979	3	3
1885	14,520	11	17	1902	74,787	16	12
1886	20,399	4	18	1903	57,620	7	9
1887	17,115	18	15	1904	62,096	17	1
1888	16,507	9	3	1905	57,596	18	20
1889	17,748	7	3	1906 (March quarter)	7,492	2	20
1890	13,040	2	19				
1891	19,837	19	7		875,958	7	7
1892	16,964	10	17				
1893	15,871	17	10				

Distribution of Gold in Lower Manuherikia Basin.

Alluvial gold in greater or less quantity is found in all the detrital deposits existing in this district. The gold-bearing deposits may be classified as under, beginning with the oldest:—

(1.) Older quartz drifts of the lacustrine series, commonly known as "granite wash."
(2.) Pleistocene high-level terrace gravels and glacier drift.
(3.) Lower river terraces, largely a rewash of the older drifts (Nos. 1 and 2).
(4.) Surface deposits of crumbling mica schist.
(5.) River-bed gravels and sands.

Older Quartz Drifts.

These extend around the margin of the old lake-basin on both sides of the valley, but they are almost everywhere obscured by the Pleistocene and younger drifts. Until sluicing operations laid them bare, they were only seen in a few places where large streams descending from the mountains had cut through the overlying deposits. Wherever these drifts are examined they are found to be gold-bearing, but it is only at the places where large streams emerge from the mountains that they have proved to be payable. For example, they have been worked with highly remunerative results at Tinker's, Cambrian's, and St. Bathan's, each situated at the lower end of a river-gorge.

It is almost certain that between Clyde and Waikerikeri, and between Waikerikeri Gorge and Tinker's, and further north along the margin of the old lake, these old quartzose drifts contain gold leads that would be of a payable character but for the heavy overburden of later drifts and glacier *débris*, and the great cost that the bringing-in of an adequate water-supply would involve.

Along the flanks of the Dunstan Range the quartz drifts are tilted on end, which necessitates the carrying-on of mining operations at a continually increasing vertical depth. In this way water-level is soon reached, and recourse must be made to hydraulic elevating, which can only be carried on successfully by the employment of large volumes of water under great pressure.

In the district forming the immediate subject of this report the quartz drifts have been worked only at Rivers's Claim, near the mouth of the Manorburn, and at Black's No. 3, in Ida Valley.

Rivers's Claim.—At Rivers's Claim the gold wash, varying from a few inches to 5 ft. thick, lies directly on the schist, and is followed by fine quartz sands and silts about 6 ft. thick, in turn followed by coarse quartzose drifts—the "granite wash" of the local miners. The gold wash consists of coarse river gravel and sand, composed of well-rounded boulders of sandstone (grauwacke), quartzite, quartz, and less-worn masses of mica schist. The bottom or floor of the claim is a rotten blue mica schist, which has been worn into a sloping bench of fairly smooth outline. This patch of gold-bearing wash and the overlying quartzose sands and drifts have been preserved from denudation by an encircling rim of hard mica schist.

The relationship of this drift to the Pliocene quartz drifts of the lacustrine series is not very clear, but it is quite certain that it does not belong to the same formation. The Pliocene drifts do not anywhere in the Manuherikia Basin overlie a river-wash of sandstone gravel. No sandstone appears until the closing member of the series is reached, which consists of sandstone and quartz without any mixture of the partially worn blocks of mica schist found in the gold wash at Rivers's Claim.

The conclusion I have arrived at is that this drift is younger than the sandstone gravels of the Manuherikia lacustrine series, and is the drift which, when consolidated by the infiltration of siliceous waters, formed the deposits of cement-stone found around the margin of the old basins.

Black's No. 3.—No work has been done here for some years. The old workings have fallen in, and little or nothing regarding the succession and character of the lacustrine beds can now be gathered from a surface inspection of the ground. I examined this field in 1888, and in my departmental report* to Sir James Hector regarding the geological conditions and future prospects wrote as follows:—

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* Park, Geol. Reports and Explorations, 1888–89, pp. 21–22

To accompany Bulletin Nº 2, Alexandra Sheet, Central Otago Division.

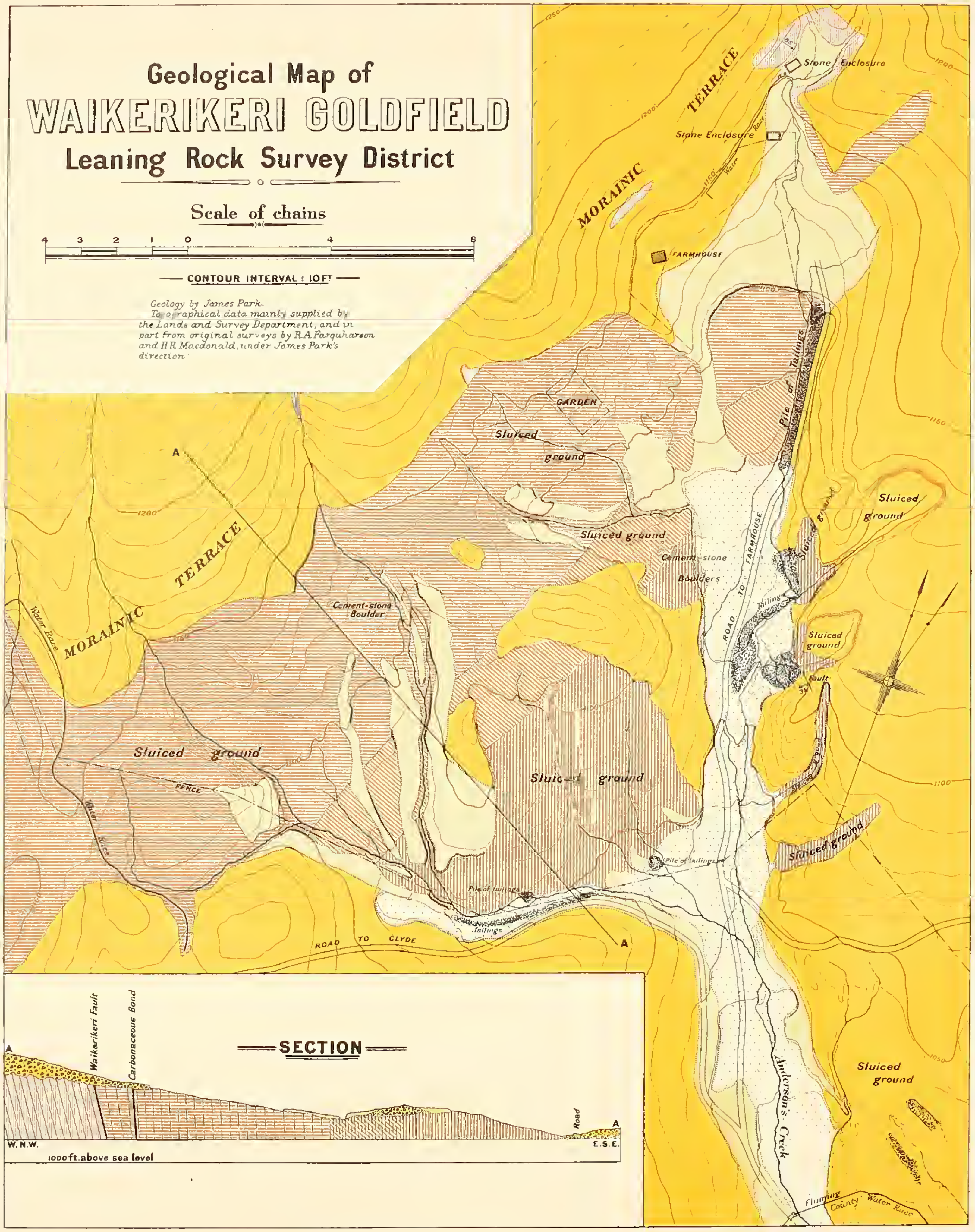
Geological Map of
WAIKERIKERI GOLDFIELD
Leaning Rock Survey District

Scale of chains

4 3 2 1 0 4 8

CONTOUR INTERVAL : 10 FT

Geology by James Park.
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A. Farquharson and H.R. Macdonald, under James Park's direction



Reference to Geological colours

RECENT	PLEISTOCENE		PLIOCENE Manuherikia Series				AGE? Maniototo Series
⠿	▭	■	▨	▥	▧	▤	▭
Loess *River Beds*	*River Terraces* *Modified Glacial Drift.* *Old Fans*	*High-level Terraces* *Glacial Drift*	*Cement Stones*	*Sandstone Gravels*	*Quartz Drift*	*Clays & Sands*	*Mica Schist*

N.Z. GEOLOGICAL SURVEY

JAMES MACKINTOSH BELL
Director.

Drawn by G. P. Wilson.

2500. 06. 787

By Authority: John Mackay, Government Printer.

" The deep lead, or, more appropriately, deep workings, in this [Poolburn] valley, formerly known as Black's No. 3 Diggings, are situated on the eastern slopes of Raggedy Ridge. The sequence of the lacustrine deposits, at the base of which the auriferous wash occurs, is well exposed at the old workings, which follow in a north-and-south line the outcrop of the wash. In the mode of their deposition, origin, and character the strata here are in every respect similar to those found at Hill's Creek, Naseby, St. Bathan's, Tinker's, Drybread, and all the other localities on the margins of the old lake-basins where they have escaped denudation. They were deposited contemporaneously, and, the same causes being in operation all over this area, their sequence is always the same. But the character of the sediments was subject to several outside influences, such as the velocity and set of currents, the inflow of streams from the adjoining mountains, and the nature of the rocks whence the material was originally derived. Allowing for the local variations caused by these, it is found that the general character, as well as the sequence, is the same at all places situated on the margins of the old basins. At the deep workings at Ida [Poolburn] Valley the deposits consist of the following members, in descending order : (1) Blue and grey bedded sands and clays ; (2) rusty ferruginous quartz grits ; (3) black carbonaceous quartz sand ; (4) grey quartz sand (very local) ; (5) white clay (very local) ; (6) auriferous wash ; (7) white clay. These beds have been subjected to considerable local disturbances, and dip in different directions within short distances. At the workings farthest up the Poolburn they dip west—that is, towards the schists—at an angle of 45°. At this place the auriferous wash was worked along the outcrop as deep open-trench workings to a depth of 15 ft. to 20 ft. ; and, when this system could no longer be pursued with safety, shafts were sunk on the wash, which was raised in buckets. The shafts were of various depths, according to the dip of the wash and the appliances available for sinking. The greatest depth reached was 200 ft., but most of the shafts were much shallower than this. At the point where the road to the German Hills Diggings leaves the slopes of Raggedy there is an isolated patch of the schists, on the gorge side of which the strata dip to the east—that is, towards the Poolburn Stream. As a result of this direction of dip the auriferous wash rises into shallow ground, lying on stiff white clays close to the underlying felsitic schists, which are here as much decomposed as at Green's Reef. The same system of open-trench working has been adopted here as at the diggings higher up the flat, but very little attempt appears to have been made to follow the wash to the dip, probably on account of the inflow from the Poolburn. With respect to the future prospects of the deep workings of the Ida Valley, it is obvious that three main conditions are necessary to insure success—viz., an auriferous wash yielding payable results ; an extended area of payable ground ; and last, but not least important, skilful mining. With regard to the first condition, the payable character of the wash is admitted by all who have worked on the field, and their evidence is confirmed by the nature of the old workings, which would not have been undertaken unless the results were worth the risks incurred. Next, with respect to the extent of the auriferous wash, it is probable that most of the shallow ground has already been worked, so that future workings would be confined to the deep ground. The lacustrine strata extend along the flanks of Raggedy Ridge from the head of the Poolburn to the gorge, and there can be little doubt that the auriferous wash which is always at the base of this series is also present ; but there is less certainty as to its payable character along the whole length of this extended lake-margin. The presence of the wash, if not its auriferous nature, could easily be ascertained by boring at well-selected points. The black carbonaceous quartz sand, which is the equivalent to the lignite found at other places in this area, overlies the wash, and, being a characteristic and well-marked horizon, always present in the Ida Valley, affords an effective check and guide as to the progress of the boring. The wash is a rough, subangular gravel, composed of quartz sand, pebbles, and fragments of mica schist. It varies in thickness from 5 ft. to 30 ft., and is said to carry gold wherever it is touched.

" The principal and, in fact, the only reason given for discontinuing the digging at this place is the depth of the ground and the danger attending the mining operations. The wash is inclined at high angles, and is enclosed in loose porous strata, in which it is difficult to sink by the ordinary means adopted in mining. The loose quartz sand, known to the diggers as 'drift,' when wet is little better than a quicksand, and precautions would have to be taken to keep it out of the workings."

Pleistocene Gravels and Glacier Drift.

These are chiefly developed in the area lying between Clyde and Alexandra, and between Waikerikeri and Springvale, forming the high-level terraces of the Moutere Run. They everywhere contain a little gold, but up to the present time no lead has been found in them sufficiently rich to be payable. On the other hand, the concentrated and re-sorted gravels and sands on the floor of the small streams, or more properly dry gullies, which intersect the high-level terraces from Clyde to the Waikerikeri Gorge and from Alexandra to Springvale and a mile beyond, although not rich, have been payable where water could be brought to bear on them. They have long since been worked out, excepting some small areas between Springvale and Chatto Creek. The Waikerikeri goldfield, where a good deal of ground has been turned over, was little better than a "hatters'" diggings in its best days.

Re-sorted Glacier Drift and Gravels.

These form the river-terrace or bench on each side of the Clutha between Clyde and Alexandra. This terrace, which varies from 60 ft. to 90 ft. above the river-level, is composed partly of re-sorted material from the adjacent Pleistocene terraces and glacier drifts, and partly (perhaps mainly) of material brought down from the upper reaches of the Clutha. The gold in this terrace has the fineness of the upper Clutha gold, averaging about 955. It is easily distinguished from the Manuherikia gold, which has a fineness of about 970.

Both banks of the terrace from Alexandra to Clyde were cradled or sluiced for gold over thirty years ago, and in some places proved very rich. Of late years the edge of the terrace has been worked by dredges, which have turned over hundreds of acres in the seach for gold.

An old channel of the Clutha passes through the recreation-ground at Alexandra, joining the Manuherikia immediately opposite the reserve. The contour of the old channel, as indicated by the isolated outcrops of mica schist in the township, leads to the belief that a lead of gold passes under this part of Alexandra. This lead lies below water-level, and to work it successfull would be difficult and costly.

Surface Deposits of Crumbling Schist.

Deposits of this class are found on the higher slopes of Raggedy Ridge, between Galloway Flat and Ophir. They generally occur on gentle slopes at or near the source of some small stream, or near the crown of some flat spur. On the banks of a stream they may be mingled with water-worn wash. In other places they consist of small fragments of mica schist, quartz, sandy clay, and soil.

In the upper part of German Gullies Nos. 1, 2, and 3, and on the flat slopes behind Ophir, there is a considerable area of ground covered with gold-bearing material of this class. The pay-dirt is mostly shallow, and the gold for the most part occurs in narrow gutters or leads, often following the contour of a natural hollow or depression in the ground.

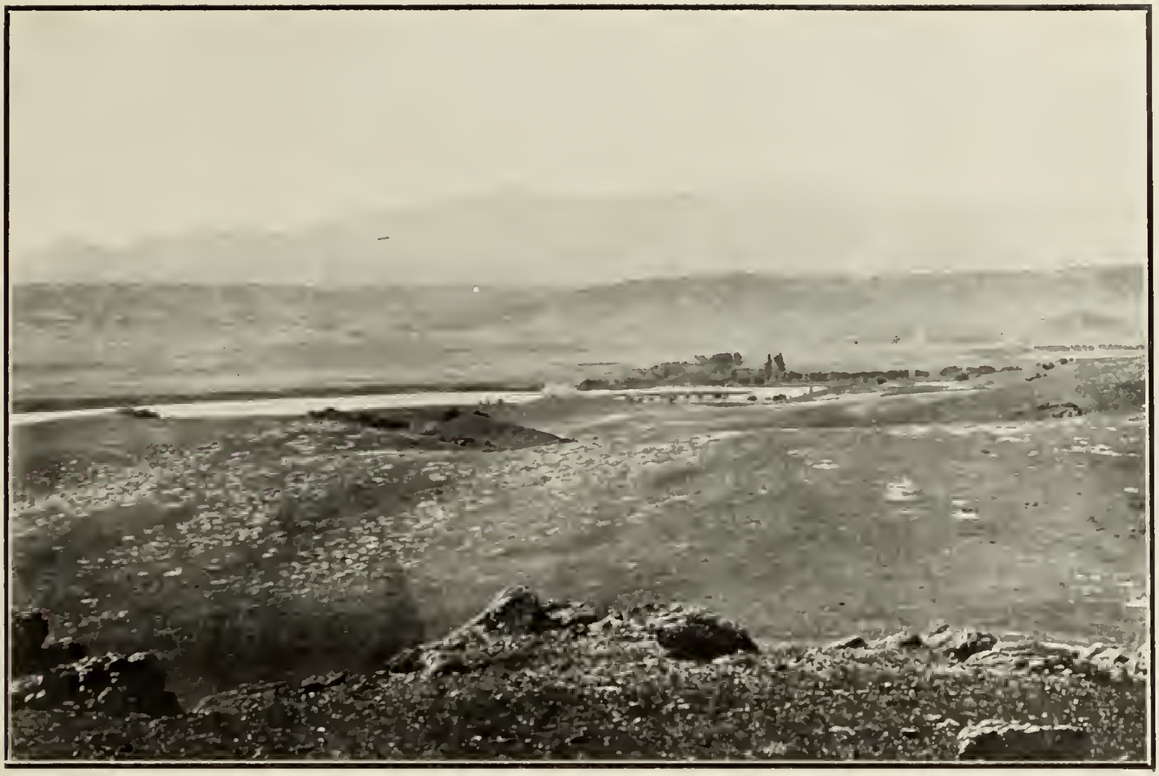
These slope deposits frequently occur in places where there is no water; and in many parts of German Gullies only those portions have been worked that were rich enough to pay the expense of sledging or wheeling in a hand-barrow to the nearest stream or water-hole.

If water were available for cradling and ground sluicing, there can be little doubt that a considerable area of gold-bearing ground along the western slopes of Raggedy Ridge could be worked with profit.

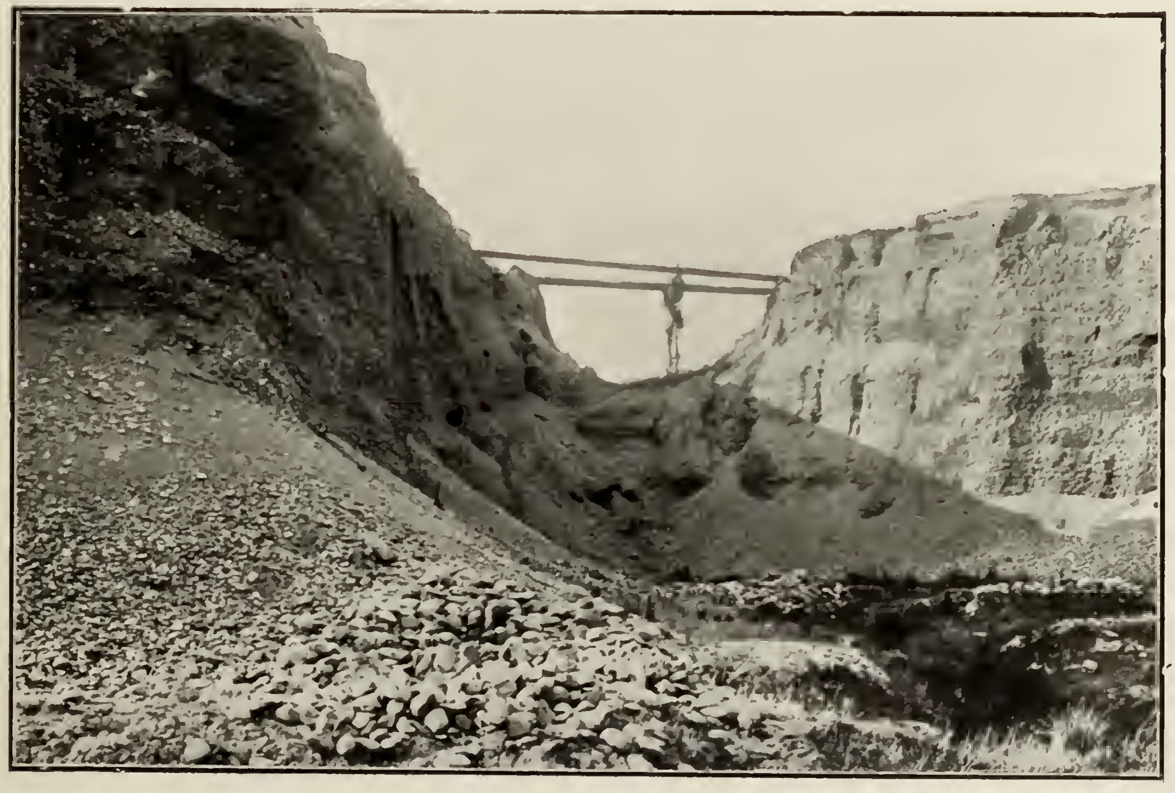
River-bed Gravels and Sands.

In the smaller streams these deposits are generally worked by ground sluicing, the course of the water being temporarily diverted to enable this to be done.

The channel of the Clutha between Alexandra and Clyde is a natural sluice-box, containing the concentrates of gold and black sand derived from the re-sorting of countless millions of cubic yards of



Manuherikia Valley, near Chatto Creek.



Gravel Face, Bonanza Claim, Galloway Station.

older terrace gravels and drifts. To reach the gold-bearing wash in the river-bed by sluicing, hydraulicking, or hydraulic elevating is impossible, and it was this which led to the introduction of dredging as a means of recovering gold from drifts situated below water-level.

Alexandra may fairly claim to be the birthplace of dredging, and it has witnessed the evolution of the primitive spoon dredge into the powerful and efficient bucket dredge of the present day.

Almost all the gold produced in the lower Manuherikia Basin is being won by dredges, of which there are no less than seventeen between Alexandra and Clyde in a distance of some seven miles.

A detailed description of dredges, dredge-construction, and dredging operations will be found in a paper prepared by my assistant, Mr. Hugh Macdonald.*

Gold-bearing Lodes.

Gold-bearing quartz is found in this district—(*a*) in the form of lodes that occupy great fault fractures, (*b*) as small veins or leaders traversing the mica schist, and (*c*) as laminated quartz in the schist.

Lodes occupying Fault Fractures.

Reference has already been made to the great dislocation which traverses the east side of the Manuherikia Valley. From Alexandra to Galloway Flat the dislocation appears on the surface as two parallel faults, about a chain apart, filled throughout the greater part of their course with lode-matter, whereby these fault fractures are now true fissure lodes.

The lode-material consists of hard yellowish-brown and blue chalcedonic or micro-crystalline quartz, often much brecciated, and generally intersected by thin veins of grey chalcedonic quartz. It varies from a few inches to 3 ft. thick, and is in many places finely slickensided on the foot-wall, which is generally clearly and sharply defined. On the hanging-wall side the lode-material passes insensibly into the mica-schist—that is, along the fault rift the schist is wholly replaced by silica, but passing upward the silicification gradually becomes less and less until it disappears. In most places the silicification does not extend more than a few feet into the schists, but along the dun-coloured hills behind Galloway Flat it extends 20 ft. or 30 ft. beyond the foot-wall.

The general strike of the lodes is about north-north-east to south-south-west, and the dip easterly—that is, towards the range—at angles varying from 45° opposite the Lower Manuherikia Bridge to 65° to 70° opposite the mouth of the Manorburn.

Fig 11

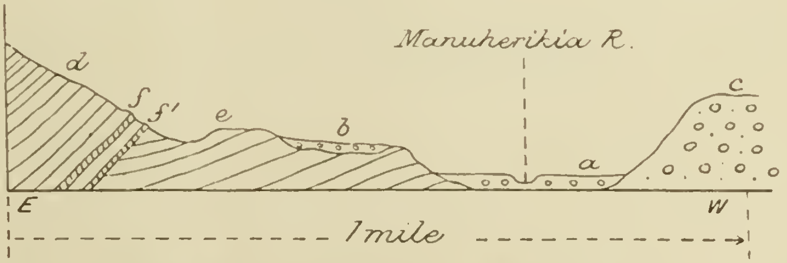


Fig. 11.—Section looking down the Manuherikia Valley, showing the Position of Lodes filling Fault Rifts.

a. River-flat gravels. *b.* Old river-channel, showing position of Richardson's gravel-cement claim. *c.* Pleistocene gravels and glacier drift (Trig. W, 700 ft.). *d.* Upper schists—argillaceous and arenaceous; strike, 132°; dip, north-east, at angles of 45° to 50° *e.* Lower mica schists sharply plicated. *f.* Upper lode, brecciated; strike, 210°; dip, 120°, at angles from 45° to 70°; width, 3 ft. to 6 ft. *g.* Lower lode: same strike and dip; width, 6 in. to 30 in.

Opposite Alexandra, near the mouth of the Manuherikia the lodes throw out a number of small lodes and fault fractures towards the north-east and east. The lodes consist of hard bluish-coloured, flinty quartz, with one slickensided wall. Along the fault fractures the schist is much shattered, and generally so impregnated with iron-oxide (limonite) as to resemble the outcrops of an ironstone lode. Samples of the ferruginous schist and lode-material were submitted to fire assay, and found to contain no gold, or only a mere trace.

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* This paper will be published in two issues of the *New Zealand Mines Record.*

The Manuherikia fault extends from Alexandra to the upper end of the valley, but it is only between Alexandra and Galloway Run that it forms a continuous lode. At the first creek north of the Bonanza Claim, and again near Ophir, there are outcrops of lodes that appear to occur in the line of the great fault.

Ophir Lode.—This crops out about a mile from Ophir Bridge on the track to Galloway. It can be traced along the surface for a distance of about 20 chains. It strikes north-east–south-west, and dips south-east at an angle of 60°. Its width varies from nil to 24 in. The lode-filling is a rusty-brown flinty quartz, passing insensibly on the foot-wall into mica schist. The rock this lode traverses is a very quartzose mica schist, in places a quartz schist. The northern extension of the lode bends towards the north-north-east. It passes under the gravel terraces behind Ophir, appearing at wide intervals where the schists crop out at the surface or are bared in old alluvial claims.

Two samples of quartz selected from the lode at a point a few chains beyond the first boundary-gate on the track to Galloway, at the place where the lode stands above the surface like a dyke, gave the following results by fire assay :—

No. 1.

	Oz.	dwt.	gr.	
Gold	0	1	0	per ton.
Silver	0	1	7	,,

No. .

	Oz.	dwt.	gr.	
Gold	0	2	15	per ton.
Silver	0	3	13	,,

It is noteworthy that the alluvial gold found in the branch of Wai-iti Stream below the outcrop of this lode was of very poor quality, possessing a fineness of only some 700 in gold ; the balance was silver.

Trig. N Lode.—Near this trig. station, on the summit of Raggedy Ridge, about three-quarters of a mile north of the point where the road from Ophir crosses to Ida Valley, there is the outcrop of a rusty-coloured lode composed of rubbly brecciated quartz cemented with iron-peroxide. It strikes N. 35° E., and dips westerly at an angle of some 55°, so far as can be determined from surface indications. In places the cap of the lode is composed almost entirely of ironstone. The lode varies from 1 ft. to 4 ft. or 5 ft. thick. It can be traced on the surface for about 85 chains. The mica schist on the foot-wall is silicified for some distance, and seamed with veins of quartz and ironstone. Samples selected from the outcrop gave the following results by fire assay :—

No. 1 (2 chains from trig.)

	Oz.	dwt.	gr.	
Gold	0	0	7	per ton.
Silver	0	1	6	,,

No. 2 (3 chains from trig.)

	Oz.	dwt.	gr.	
Gold	0	0	6	per ton.
Silver	0	0	1	,,

No. 3 (south end of outcrop).

	Oz.	dwt.	gr.	
Gold	0	3	23	per ton.
Silver	0	2	6	,,

The free gold shed by this lode is high grade, having a fineness of over 965. The silver probably exists in the form of a sulphide.

To accompany Bulletin No. 2, Alexandra Sheet, Central Otago Division.

JAMES MACKINTOSH BELL
Director.

Geological Map of
OPHIR GOLDFIELD
Tiger Hill Survey Dist.

Scale of chains

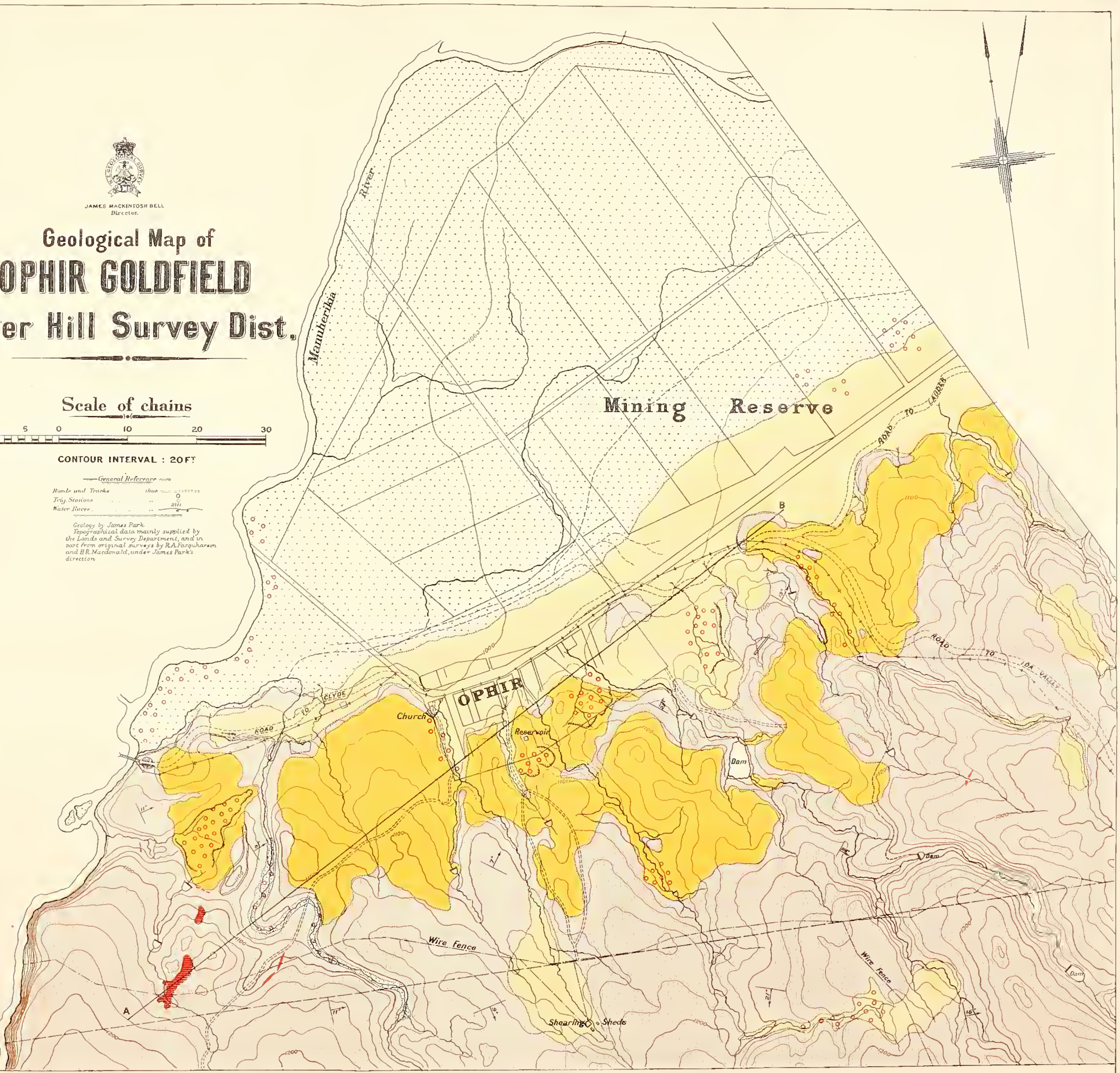
10 5 0 10 20 30

CONTOUR INTERVAL : 20 FT.

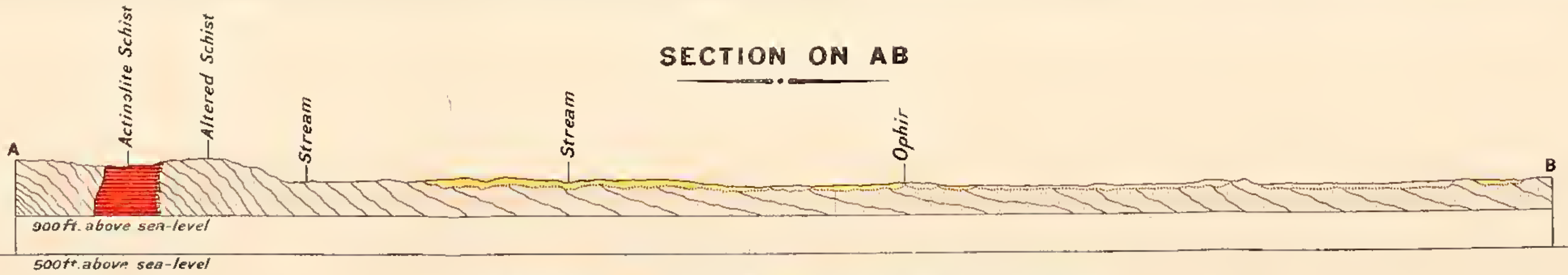
General Reference

Roads and Tracks	*thus*	
Trig. Stations	..	○ 2111
Water Races	..	

Geology by James Park.
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A. Farquharson and H.R. Macdonald, under James Park's direction.



SECTION ON AB



Reference to Geological colours

RECENT	PLEISTOCENE		AGE ?			
▨	🟨	🟧	▭	🟥	⟋	° ° °
Recent river deposits	*Schistose gravels*	*Sandstone gravels*	*Mica Schist*	*Actinolite Schist*	*Lodes*	*Old Workings*

Drawn by G. P. Wilson.

By Authority: John Mackay, Government Printer.

2500 – 06 – 788

Red Hills, Chatto Creek.—The low hills facing the railway-line near Chatto Creek are composed of decomposed mica schist, forming crumbling, greasy, gritty, micaceous clays, varying in colour from yellow to red and purple. The quartz laminæ are very thin, and subordinate to the mica. In the decomposed rock the quartz forms a fine gritty sand, dispersed throughout the clays. In the railway cutting just below the big bend in the line the schist is seen to be traversed by thin veins of rusty-coloured quartz. A sample of this quartz collected in the cutting showed the following result by assay :—

	Oz.	dwt.	gr.	
Gold	0	0	8	per ton.
Silver	0	2	6	,,

A sample of quartz, somewhat similar to the above, from the ochreous-coloured schist hill near the Fraser River flat contained a trace of both gold and silver.

None of the flinty ironstone lodes in this district have so far been shown to be payable.

Quartz Veins and Leaders.

The veins of this class are generally thin, being seldom more than a few inches thick. They are commonly gold-bearing, but only a few of them have been considered rich enough to warrant systematic prospecting. The majority appear to fill contraction or stress cracks in the schist, but a few of the larger occupy fault fractures.

Green's Reef, Ophir.—The rock in which this vein, or system of veins, occurs is a grey micaceous quartz schist, much broken and shattered, and in places sharply plicated. The micaceous matter has been altered into a fine grey greasy clay, while the quartz laminæ are broken up into small angular pieces. The schist, which lies at a low angle, is traversed by a number of small parallel quartz veins occupying fault-planes. One system of veins runs east to west, and is nearly vertical ; a second system strikes east-south-east to west-north-west, and dips north-north-east at angles varying from 45° to 50°. The veins vary from 1 in. to 12 in. thick. The quartz is grey and crystalline. The two systems of faults do not displace each other. Where the veins of one system cross those of the other, the quartz from one runs into the matrix of the other without displacement. From this it would appear that the two systems of faulting are of the same date.

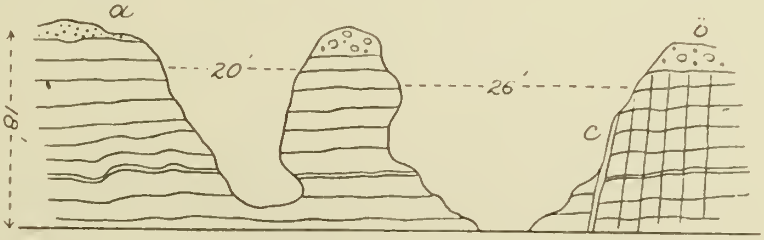


Fig 12

Fig. 12.—Section of Old Workings at Green's Reef, Ophir.
a. Surface clays. *b.* Alluvial-gold wash. *c.* Small parallel veins in micaceous quartz schist.

Thirty yards to the south-west of the old workings the quartz schists are seen to be underlain by chlorite schist.

An examination of Green's Reef was made by the writer in November, 1888, at the time when mining operations were being carried on. A detailed description* of the workings, geological conditions, and method of treating the ore is given in a report supplied at that time to Sir James Hector, then Director of the Geological Survey.

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* J. Park, Geol. Reports and Explorations, 1888-89, pp. 17-19.

Ophir Reef.—This is situated about a mile south-west of Pitches' woolshed, which is about three-quarters of a mile from Ophir. Some years ago this reef was worked by a local syndicate. A shaft was sunk to a depth of 100 ft. and a surface stope taken out. The return of gold per ton of ore crushed is said to have been satisfactory, but the venture fell through owing to the quartz pinching out at the ends and also going downwards. The reef in the stoped part varies from a mere parting to 16 in. thick. The ore consists of hard yellowish-brown and grey quartz. The walls in the stope are clean and sharply defined.

The course of the vein is E. 5° S., and it stands nearly vertical, having a slight inclination to the north. It traverses the mica schist nearly at right angles to the bedding-plane. The appearance of the walls and the brecciated character of some of the quartz would tend to show that the vein occupies a fault fracture running nearly at right angles to the ironstone lodes at Galloway, Ophir, and Trig. N.

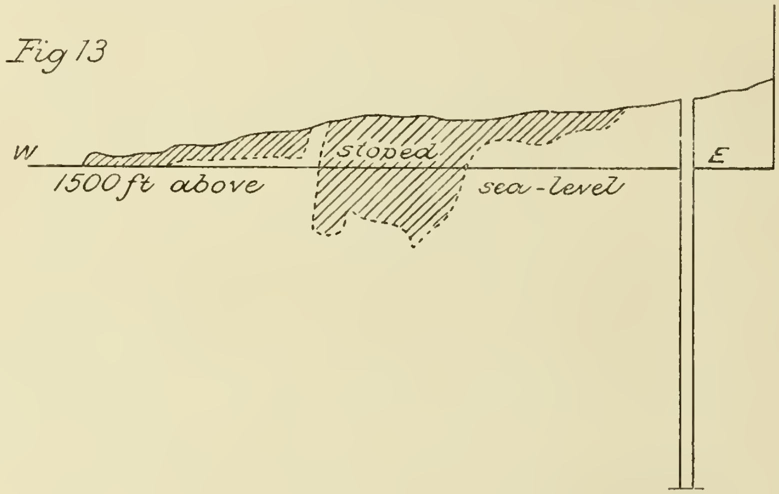

Fig. 13.—Showing Longitudinal Section of Ophir Mine Workings.

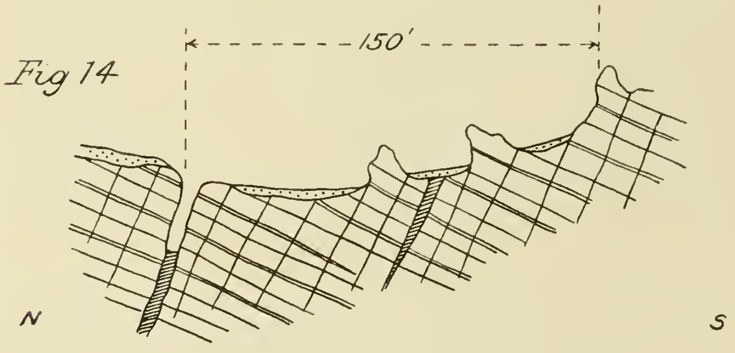

Fig. 14.—Showing Cross-section of above.

Conroy's Reef, near Alexandra.—This reef crops out on both sides of Conroy's Gully a short distance below the head of Chapman's Gully. It has been worked or prospected by small companies or private syndicates at various times during the past thirty-two years. At the time of my visits in November and December, 1905, it was being worked by Messrs. Robertson, Paget, and party, on the east side of Conroy's Gully. Here the reef runs about east–west (mag.), and dips north at an angle of 60°. It traverses flat-lying, almost horizontal, mica schist. The lode-material consists of quartz and crushed rock or mullock, varying from a few inches to 2 ft. thick. The lode has been prospected

View of Ophir Flats, looking West.

View of Ophir, looking South-west.

by several shallow pits and a shaft 40 ft. deep situated near the stream. From the bottom of the shaft there is a drive following the course of the vein in an easterly direction for some 50 ft.

The ore was being treated in a 5-stamp battery driven by an overshot water-wheel. The yield of gold per ton of ore was satisfactory, but the quantity of ore was found to be very limited. The underground workings showed that the lode pinched out going east and going downwards. In consequence of this mining operations were discontinued in March.

Conroy's Lode, on the Old Man side of Conroy's, can be traced on the surface for a distance of some 15 chains. In the early "seventies" it was worked by a small company which expended a considerable sum in sinking shallow shafts, in trenching, and driving. The main work undertaken by this company was the construction of a crosscut 600 ft. long, which was intended to act as a low-level adit; but it was started so shallow that when it reached the lode it was only 50 ft. below the surface, and was thus not only useless for the purpose for which it was intended, but also crippled the financial resources of the company. The lode varied from 6 in. to 18 in. wide, and was at this time worked out along the surface for a distance of 6 chains by a shallow underhand stope. The ore consisted chiefly of quartz and mullock, the latter often predominating. According to the statement of Mr. B. Poole,* of Clyde, the yield of gold was about 1 oz. per ton of ore crushed. Here, as on the east side, the abandonment was caused not by the grade of the ore so much as by the difficulty of obtaining a continuous supply of ore at a reasonable cost. So far as the prospective value of the lode is concerned, nothing whatever is known below a depth of 50 ft. from the surface. The course of the lode is approximately east and west. The creek cuts through the lode nearly at right angles, forming a narrow rocky channel with steep sides. The proper course to pursue in prospecting this lode would have been to drive along the lode, starting near the creek. By this means a considerable height of backs would have been available over the level, the character of the lode would have been disclosed along the whole length of the drive, and there was the possibility that the ore won during the construction of the drive would have in part paid the cost of construction.

Flanks of Old Man Range.—Small gold-bearing veins occur at or near the source of all the small streams that take their rise on the east and north sides of the Old Man Range. These veins generally run east and west, and in most cases seem to follow the course of great joint planes or fault fractures. They are mostly inclined at steep angles. The vein-filling consists of rubbly quartz and mullock. It is seldom continuous for a great distance, but occurs in long thin lenses, which succeed each other in depth and linear distance. Many of these veins have been opened up by prospecting trenches and shafts, but none of them, with perhaps the exception of White's Reef, have been found to contain payable gold. But although they have not proved payable to the direct operations of man, these lodes have been an important factor in the gold-production of this region. Most of them have been denuded hundreds of feet, some of them thousands, and the released gold has been scattered among the alluvial drifts in the adjoining valleys. So far as our present knowledge goes, they are the chief, if not the only, source of the alluvial gold found on the south-west side of the Clutha.

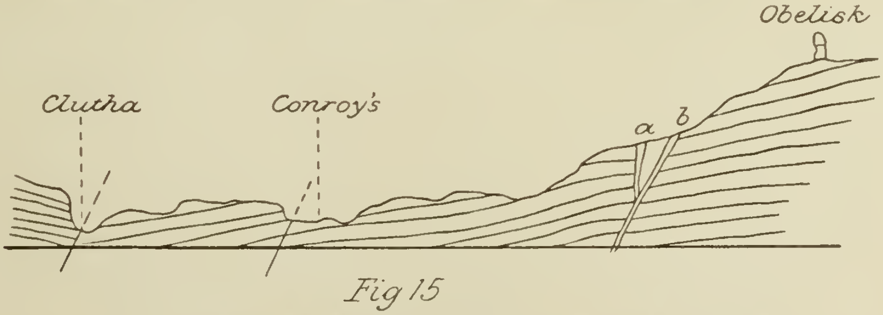

Fig. 15.—Section from Clutha to Obelisk on Old Man Range.
a and *b*. Mullocky veins in mica schist.

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* Ulrich, "Geology of Otago," 1875, p. 200.

Laminated Quartz in Mica Schist.

It has been maintained by some writers that the laminated quartz of the mica schist is the source of the alluvial gold throughout Otago. This was the opinion of Professor Ulrich,* but the evidence he adduces is by no means convincing. The quartz veins described above often throw out thin spurs that run parallel with the bedding-planes of the mica schist, and might easily be confounded with schist laminæ.

At the head of Chapman's Gully there is a quartz drift composed of greasy clays and small pieces of angular quartz derived from the decomposition of the adjacent micaceous quartz schists. The quartz fragments often contain visible gold, but an examination of the stone discloses the fact that it is not laminated but vein quartz. The rock is traversed by thin veins of quartz and irregular seams of quartz running parallel with the bedding-planes, but the latter are seen to be slip bands that have been filled by segregation, probably at the time the ramifying veins were formed.

Origin of Alluvial Gold.—The gold in the bed of the Clutha and in the terrace on which Alexandra stands has an average fineness of 955, and is easily distinguished from the gold of the Manuherikia Valley. It has manifestly been carried down by the river from some point above Clyde, probably even beyond Cromwell, but to locate its exact source is beyond the scope of this report.

The alluvial gold from the Manuherikia Valley has an average fineness of 970. In my opinion, it is mainly derived from the numerous small gold-bearing veins that traverse the schists on the flanks of the Old Man Range, Raggedy Ridge, and Dunstan Mountains.

In the creek workings near its source the gold is rough, shotty, or hackly, sometimes crystallized, and often enclosed in a quartz matrix, forming what is known to miners as "specimen gold." Lower down the streams, where it occurs in water-worn wash, the gold is more rounded, and specimens are scarce; while in the larger streams and rivers it commonly occurs in flattened grains or pieces resembling a mixture of large and fine bran, the result of the pounding it has been subjected to among the gravels and boulders that travel along the river-bed. In the larger streams specimen gold is very rare, the pounding of the travelling gravels having in nearly all cases released the gold from its quartzose matrix.

Mr. T. A. Rickard,† in his paper on "The Goldfields of Otago," discusses the origin of the alluvial gold in Otago at some length. He summarises his views in the following statement: "That the bulk of the gold of the extensive alluvium of Otago came from the degradation of the known lodes, I do not believe. The mere proportion of the known extent of the one to that of the other may be an insufficient basis for such a conviction, for in this country, as in other comparatively new regions, the mineral deposits are only in an infancy of development; yet this fact has some weight. The chief evidence comes, however, from the known relations of the lodes to the country rock, and from the character of the alluvial gold itself. It is not necessary to recapitulate the observations made on the lodes—how they are for the most part ore-channels, the auriferous filling of which shades off into the surrounding country, as regards both gold-contents and structure. The gold of the alluvium has not that shotty character familiar to the digger of Australia or California. An exception must be made of the small placer deposits of some of the mountain-streams, the nuggety gold of which is easily traceable to its source in the neighbouring quartz veins. Such gold is, however, quite exceptional, and altogether of a character different from that of the great fluviatile and lacustrine deposits of the Clutha and Shotover, the wealth of which is contained in the very fine flaky gold, which is like bran and notable for its uniformity of size and wide distribution. It has a character making it easy of recognition among samples coming from other districts. It is also remarkable that quartz stones showing gold are of very rare occurrence at the Bluespur or in the gravel-deposits of the Clutha and Shotover. The gold came, I believe, as did the gravel through which it is distributed and the cement in which it is often imbedded,

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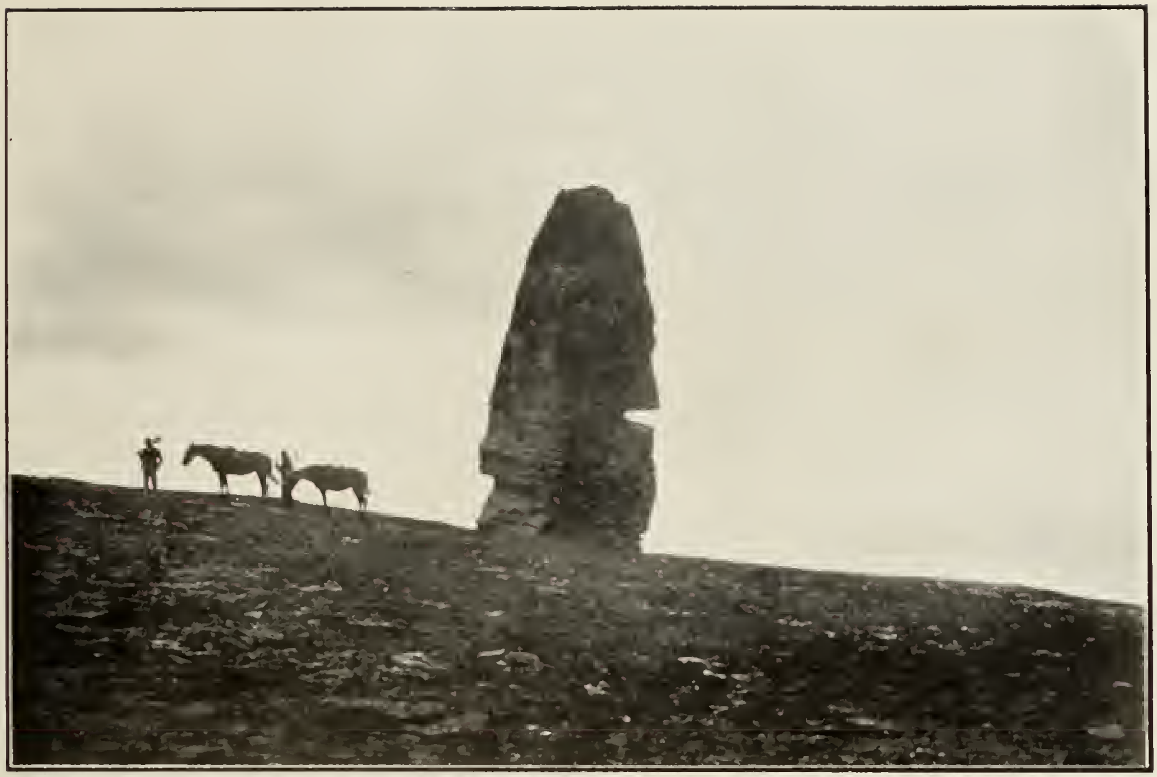
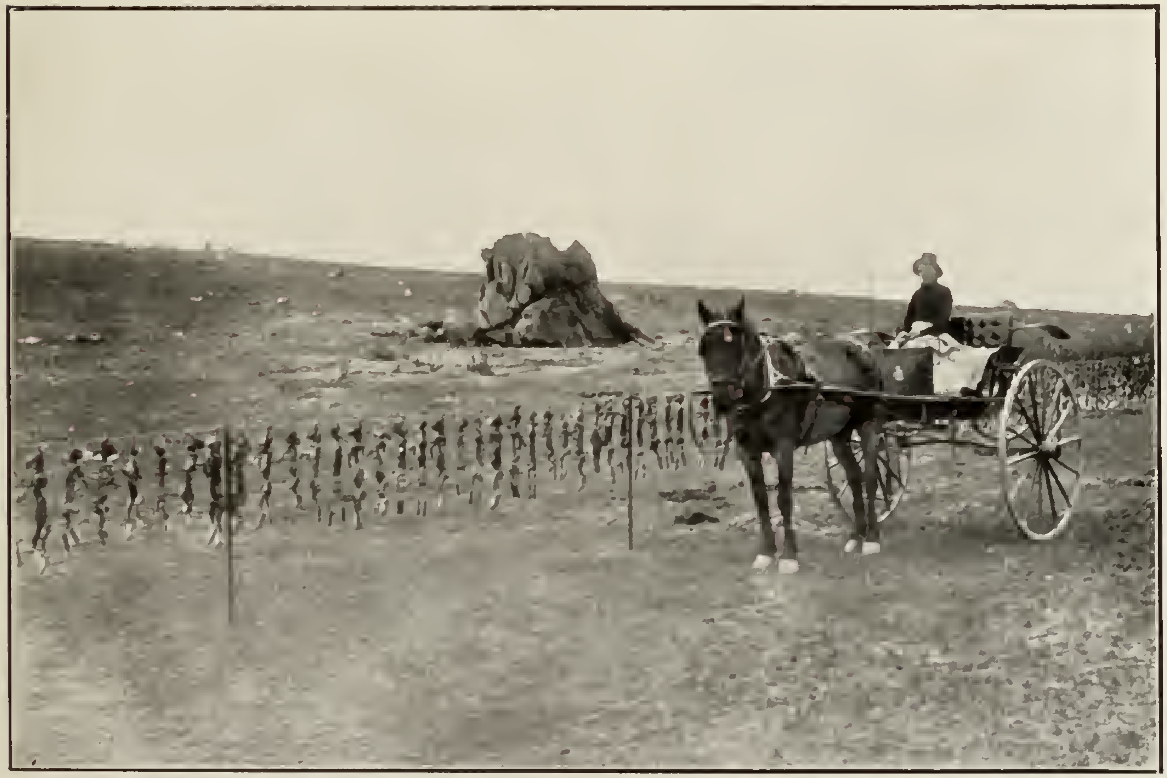
* Ulrich, "Geology of Otago," 1875, p. 157.

† Trans. Am. Inst. Min. Eng., vol. xxi, 1893, pp. 442–73.



"The Obelisk," on Summit of Old Man Range.



Lower End of Clyde Moraine, on Road from Springvale to Clyde.

not from the few comparatively insignificant quartz lodes, but from the great mass of the quartzose schists. The quartz folia which form the characteristic feature of the schists of Otago are known in places to carry gold far outside the limits of any of the particular lode-channels which also traverse them. One could with perfect reason regard the whole belt of quartzose schists as one large bed-vein, in which the lodes now worked are merely small cross-veins—a large gold-vein, through which for ages the glaciers have ploughed an easy way, cutting furrows from which the quartz and schist have been swept by wind and rain into the swift waters of the Clutha and Shotover, to be laid down by them in the form of the great banks and terraces of gold-bearing alluvium which to-day are the chief depositories of the mineral wealth of Otago."

The origin of the gold contained in the quartz grits so widely distributed throughout Otago has always been a prolific subject for discussion among miners and geologists, and the last word has not yet been said. Among geologists who have studied this problem, perhaps none has devoted more time to its investigation than Mr. A. McKay, F.G.S., and for this reason the opinion of none deserves more consideration. And although I do not see eye to eye with Mr. McKay on this subject, it is only right that his views should be recapitulated in this place. Speaking of the quartz grits of Otago and their distribution he says,* "At one time these quartz grits seem to have been an almost continuous deposit over all the low grounds and middle heights throughout Otago and Southland, and to have occupied a considerable area of southern Canterbury as well. Subsequent to the close of the Cretaceous period movements of the land took place by which portions of the grit formation were elevated to positions 4,000 ft. to 5,000 ft. above the sea, and at the same time other parts were deeply involved along lines of fault at unequal elevations, thus exposing in the one case the uplifted area to rapid denudation, and in the other case the upturned edges of the involved part to the same influence. In this manner great destruction of the quartz grits took place, and it is a matter for marvel that so much of them has been preserved to the present time. Considering the comparative paucity of reef quartz over the whole of Otago and Southland, it is evident that reefs of quartz could not have supplied such a great formation of residual grits, even granting that an enormous denudation, far greater than what is usually supposed, did take place. The lower schist formation of central and northern Otago is strongly foliated with laminæ of quartz, which, though resembling, can in no sense be regarded as vein quartz, and this is evidently the source whence has been derived the great bulk of the quartz grits at the base of the coal-bearing formation; and as these quartz foliæ are known to carry gold—*e.g.*, at Skipper's Creek, on the Shotover, at Green's Reef, near Ophir, and at other places—such quartz foliæ must be regarded as the principal source of the alluvial gold of Otago. It has, however, to be stated here that, while much gold has been obtained from the quartz drifts, the larger pieces of quartz in the drifts, varying from 2 in. to 5 in. in diameter, do not contain gold, numberless trials having failed to show its presence. This has been regarded as showing that the country quartz does not contain gold, and could not have yielded the alluvial and cement gold of the quartz drifts. However, it has been shown that the denuded parts of existing reefs were as unlikely as a source of the twenty-three to twenty-four million pounds' worth of gold that has been obtained from the goldfields of Otago; and it is an undoubted fact that, whether in the solid parts of the quartz foliæ or no, gold is found in association therewith, and, as is often the case in connection with vein quartz, the casing and friable margins often contain gold, while the solid quartz of the middle part does not. So, also, this may be characteristic of the country quartz occurring as foliæ in the mica schist. Other sources of gold may be suggested, such as bodies of iron-sulphide or of oxide of iron (hæmatite); but aggregated bodies of these ores are comparatively rare, and the character of the gold in Otago is generally against the assumption. Other sulphide ores, such as copper or antimony, may be suggested, but these also are not likely on investigation to prove satisfactory.

"The gold of Otago must therefore be regarded as mainly having origin in the schists, and in near association with the quartz foliæ that characterize the middle and lower divisions of the schists, and is but little due to the quartz reefs occurring in the same rocks, as at but few places are the foliated schists rich enough to pay for working."

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* A. McKay, "Gold Deposits of New Zealand," Wellington, 1903, p. 67.

Both Rickard and McKay incline to the belief that the bulk of the alluvial gold was derived from the quartz laminæ of the mica schist. The evidence adduced is, however, not very convincing. Their view is based, apparently, more on general considerations than specific facts. The subject possesses more than an academic interest: and the view that the gold is mainly derived from the interlaminated quartz of the schist can only be established by minute investigation of authenticated occurrences.

Black-sand Concentrates.

The rare metals are commonly associated with metamorphic or crystalline rocks, and when present in such rocks are easily distinguished in the heavier sands that collect in the streams draining the district. In order to ascertain what mineral constituents were contained in the sands of the Clutha and upper Poolburn, samples of the concentrates obtained from dredges were submitted to Dr. J. S. Maclaurin, Government Analyst, with the following results:—

No. 1.—From Hartley and Riley Dredge, near Cromwell.

Magnetite	1,510	grammes.
Non-magnetic material	550	,,
Lead shot	4	,,
	2,064	grammes.

The sample was tested for gold, platinum, tin, and rare metals, with the following results:—

Gold	7 oz. 9 dwt. 1 gr. per ton.
Platinum	Nil.
Iridium	Nil.
Tin	Nil.

Rare earths, thorium, &c., no appreciable amount; certainly less than 0·2 per cent.

No. 2.—Sample from Poolburn Dredge, Upper Ida Valley.

Magnetite	326	grammes.
Non-magnetic material	1,254	,,
Lead shot	1	,,
	1,581	grammes.

Gold	13 oz. 18 dwt. 18 g. per ton.
Platinum	Trace.
Iridium	2 dwt. 17 gr. per ton.
Tin	Nil.

Rare earths, thorium, &c., no appreciable amount; certainly less than 0·2 per cent.

The following interesting and suggestive results relating to the extraction of gold from black-sand concentrates have been obtained by Mr. D. B. Waters, A.O.S.M., of the Otago School of Mines:—

NO. A.—ALPINE NO. 2 DREDGE, BELOW CROMWELL.

Total weight of sample, 54,000 gr.

Sizing Results.—

1. Left on 8-mesh sieve, 9·26 per cent., containing by fire assay—

Gold	1 dwt. 7 gr. per ton.
Silver	3 dwt. 22 gr. ,,

2. Left on 20-mesh sieve, 59·9 per cent., containing—

Gold	Trace only.
Silver	5 dwt. 16 gr. per ton.

3. Passed through 20-mesh sieve, 30·8 per cent., containing—

Gold	3 oz. 17 dwt. per ton.
Silver	5 dwt. 21 gr. ,,

Magnetic-separation Results.—

No. 3 product from the above sizing experiments was treated by magnetic separation.

4. Non-magnetic, 11·2 per cent. of original sample—containing gold, 9 oz. 11 dwt. 10 gr. per ton
5. Magnetic, 19·6 per cent. of original sample—containing gold, 1 dwt. 7 gr. per ton.

Amalgamation Test.—

A portion of No. 3 was subjected to amalgamation, and from 11,000 grains of sample 1·458 gr. of gold were obtained, representing a return of 4 oz. 6 dwt. 5 gr. per ton.

NO. B.—RISE AND SHINE DREDGE, ABOVE CROMWELL.

Total weight of sample, 20 lb.

Sizing Results.—

1. Left on 20-mesh sieve, 40 per cent., containing—

Gold	7 gr. per ton.
Silver	22 gr. ,,

2. Passed through 20-mesh sieve, 60 per cent., containing—

Gold	7 dwt. 19 gr. per ton.
Silver	1 dwt. 7 gr. ,,

A portion of No. 2 was passed through a 30-mesh sieve, the assay results being as under :—

Over size :	Gold	6 dwt. 19 gr. per ton.
	Silver	1 dwt. 7 gr. ,,
Under size :	Gold	8 dwt. 11 gr. ,,
	Silver	3 dwt. 22 gr. ,,

These tests show that to screen finer than 20-mesh will not be of assistance in the recovery of the gold.

Magnetic Separation.—

A portion of No. 2 was magnetically separated, the results obtained being as under :—

Non-magnetic, 47·5 per cent. of No. 2—

Gold	12 dwt. 9 gr. per ton.
Silver	5 dwt. 21 gr. ,,

Magnetic, 52·4 per cent. of No. 2—

Gold and silver	Practically nil.

These results show that by sizing and magnetic separation the whole of the values contained in the black-sand concentrates can be obtained in 28·5 per cent. of the total.

ANTIMONY.

A small antimony-bearing lode crops out on the right bank of the Clutha about 15 chains above Alexandra Bridge. It is enclosed in mica schist, strikes about north-north-east – south-south-west, and underlies to the W.N.W. at an angle of 45°. The gangue or matrix of the ore is rusty-coloured crumbling quartz, in which the antimonite occurs as short irregular bands from 2 in. to 6 in. thick. The lode crops out at another point about 15 chains further along the road to Clyde.

Various attempts have been made to work this lode, the last in 1900–1, by Messrs. Stewart and Blair, who sank a shallow shaft and carried out a good deal of useful prospecting-work, but without disclosing the existence of a payable lode.

In a place so remote from the sea it would require a continuous lode of first-class ore not less than 6 in. thick to yield profitable returns on only a small capital outlay. The indications disclosed at the surface do not warrant any great expectations.

SCHEELITE.

A specimen of scheelite of first-class quality, weighing about 3 lb., was found in the bed of Conroy's Creek in the year 1900, but so far all efforts to trace the ore to its source have been unsuccessful. It may have come from the flanks of the Old Man Range; but this is not quite certain, as there is always the probability that it may have been derived from the high-level Pleistocene drift of the Clutha.

Scheelite is a valuable ore, and finds a ready market in Europe. It commonly occurs in mica schist and altered sedimentary rocks, and for this reason gold-prospectors in this part of Central Otago should always be on the look-out for indications of it in creek and river gravels.

COAL.

Central Otago is so completely destitute of forests or of native vegetation suitable for fuel that the lignite found at the base of the Manuherikia lacustrine series has been one of the main factors in the settlement of the country and development of the dredging industry. Without this natural fuel settlement would have been set back probably not less than a quarter of a century.

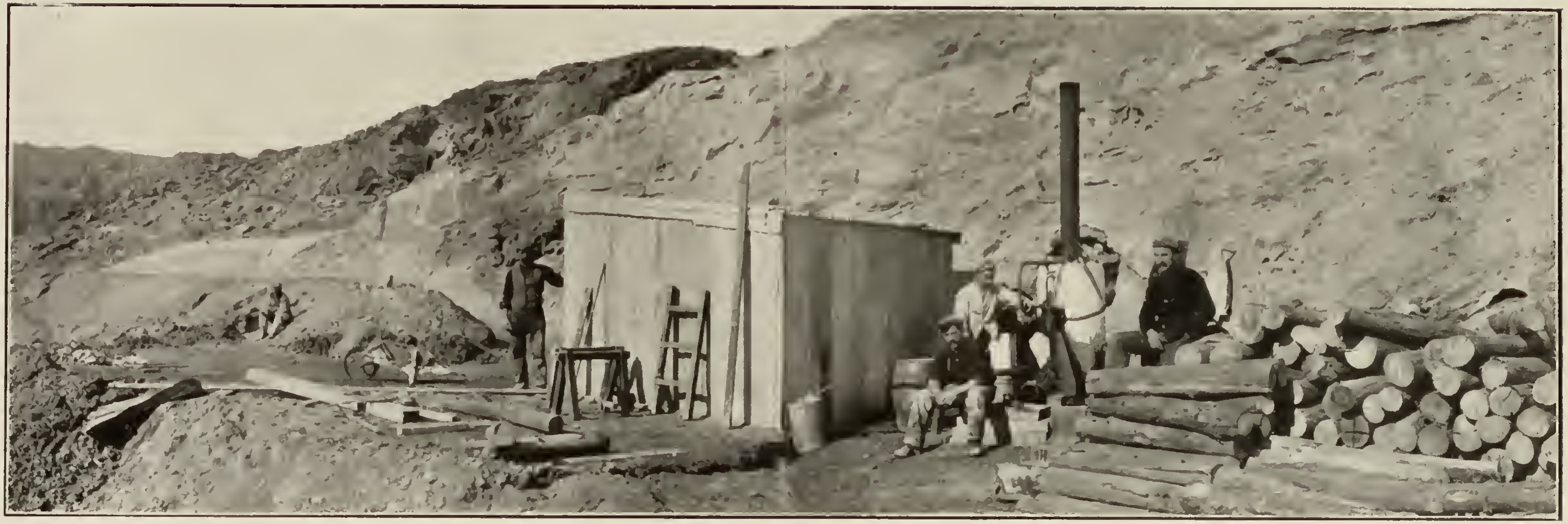
The lignite-coal field extends from Dairy Creek Gully to Clyde. The seam passes below the township and stretches down the Clutha to the boundary of Alexandra, whence it extends up the Manuherikia River to the Galloway crossing of the river.

The lignite crops out at the surface at Dairy Creek, on the bank of the Clutha near Clyde Bridge, along the floor of the Clutha below the mouth of the Fraser River, and at several points in the valley of the Manuherikia between the boundary of Alexandra and the mouth of the Manorburn. It will thus be seen that the lignite crops out around the margin of the old lake-basin.

No outcrop is known above the Galloway Crossing, near the Manorburn, but the lignite-measures extend up the valley to Chatto Creek and Omakau, and there is no reason to believe that the lignite does not exist in this area.

Owing to the disposition of the coal-bearing beds with relation to the surface-contours, it would be impossible to determine the presence or absence of lignite without resort to boring. Suitable sites for prospecting boreholes have been marked on the Leaning Rock sheet as a guide in the search for lignite at some future date.

At Lauder and other places outside the limits of the district under review there are several valuable outcrops of lignite. No outcrops are known to exist in the upper Poolburn drainage-area.



ANTIMONY MINE NEAR ALEXANDRA SOUTH

[Photo by McEachen.

Dairy Creek Lignite.

The total thickness of the seam is about 44 ft., including three clay partings, as under, No. 1 being the upper seam : No. 1 seam, 9 ft. thick ; clay parting, 3 ft. thick. No. 2 seam, 10 ft. thick ; clay parting, 3·5 ft. thick. No. 3 seam, 8 ft. thick ; clay parting, 0·5 ft. to 2 ft. thick. No. 4 seam, 9 ft. thick.

The geological sequence of rocks is as follows, beginning at the bottom : (1) Mica schist (the basement rock) ; (2) sands and fireclay ; (3) lignite-seams ; (4) shaly clays ; (5) glacier moraine. The relative position of these is shown in the accompanying cross-section.

Fig 16

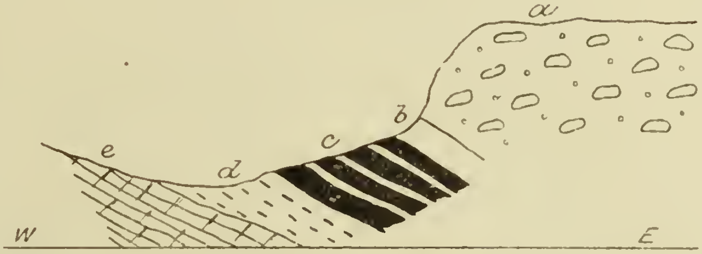


Fig. 16.—Section of Dairy Creek Lignite-measures, near Clyde.
a. Glacier moraine. *b.* Clays. *c.* Lignite-seams. *d.* Sands and clays. *e.* Mica schist.

The mica schist strikes north–south (mag.), and dips east at angles varying from 30° to 35°. The seams of lignite conform to the dip of the schist, their average inclination being about 33°.

The vertical thickness of sands and clays separating the schist and lignite is believed to be somewhere about 30 ft., but there is no section in which this can be verified. In places it may be more, in others less.

Before the formation of the great moraine the coal-measures were scoured out by the Clutha almost down to the lignite. For this reason the cover of original strata overlying the lignite is very thin. It consists of greasy shaly clays containing numerous casts of a small bivalve, probably a fresh-water Unio. The greatest thickness of these clays to be seen in the gully is exposed in Murrin's old drive, where about 16 ft. of shaly clays are exposed over the roof of the lignite.

The lignite-seams are a good deal shaken, and have been worked by different owners without much skill or any attempt at development on a definite or systematic plan. In any case the lignite is inferior of its kind, the output small, and the market precarious, being to a great extent dependent on the dredging industry.

Average samples of the four seams gave the following results by analysis :—

Analyses by H. Lovell.

	No. 1.	No. 2.	No. 3.	No. 4.
Fixed carbon	26·55	23·20	26·70	20·09
Hydrocarbons	42·36	41·70	40·50	49·69
Water	25·00	23·50	25·00	23·00
Ash	4·80	10·00	5·80	5·40
Sulphur	1·29	1·60	2·00	1·82
	100·00	100·00	100·00	100·00

Evaporative Power.

	No. 1.	No. 2.	No. 3.	No. 4.
Pounds of water evaporated by 1 lb. of lignite*	3·45	3·02	3·47	2·61

The lignite from seams Nos. 1, 2, and 3 is used for steam purposes, from No. 4 for household purposes.

Since my last visit to Dairy Creek, Mr. J. Smith, the mine-manager, reports that he has discovered a thin seam of oil-shale, 8 in. thick, a few feet above the top seam. Owing to the pressure of water and the treacherous roof, little or nothing has yet been done to ascertain the extent of the find. The shale is high grade. It is of a buff-brown colour, and very fissle. What is probably the same seam crops out at Waikerikeri, in the old workings at Anderson's Creek. It is close to the great fault, and is much crushed and broken.

Clyde Coal-area.

The lignite and lignite-measures crop out both above and below the suspension bridge over the Clutha, and dip at a low angle underneath the township, which is thus built on a coalfield. Shafts or boreholes put down anywhere between the Post-office and the west end of the railway-yard should strike the seam of lignite at a depth varying from 100 ft. to 200 ft., according to the distance back from the line of outcrop.

Some time in the "seventies," so I was told by local residents, the seam was worked on the bank of the river at a point nearly opposite the Anglican Church. It is somewhat surprising that this coal-area has been neglected so long.

Blackman's Gully.

Lignite crops out at this place in a small basin in the foothills behind the settlement of Earnscleugh, on the Fraser River. It was worked at one time, but the old workings have fallen in, and very little information with respect to the size or disposition of the seam can be obtained form a surface-inspection of the ground. So far as I could make out, the strike of the seam is north-west – south-east, and the dip south-west at an angle of about 45°.

The coal-measures are covered with a heavy deposit of morainic material.

The section exposed at the old workings is as shown below.

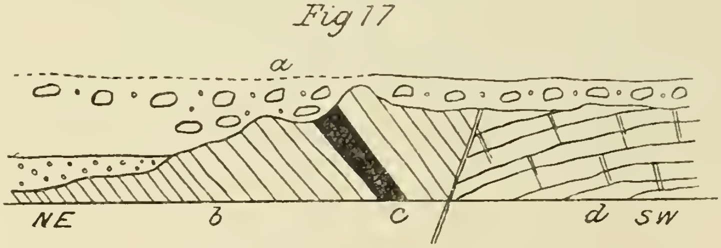


FIG. 17.—SECTION OF COAL-MEASURES AT BLACKMAN'S GULLY.

a. Morainic material. *b.* Blue sandy clays. *c.* Lignite overlain by quartz sands and drifts. *d.* Chlorite schist.

Coal Creek.

This lies about a mile and a half further to the westward, along the foothills of the Old Man Range. At this place there is a narrow strip of the coal-measures nipped up between two faults in a narrow

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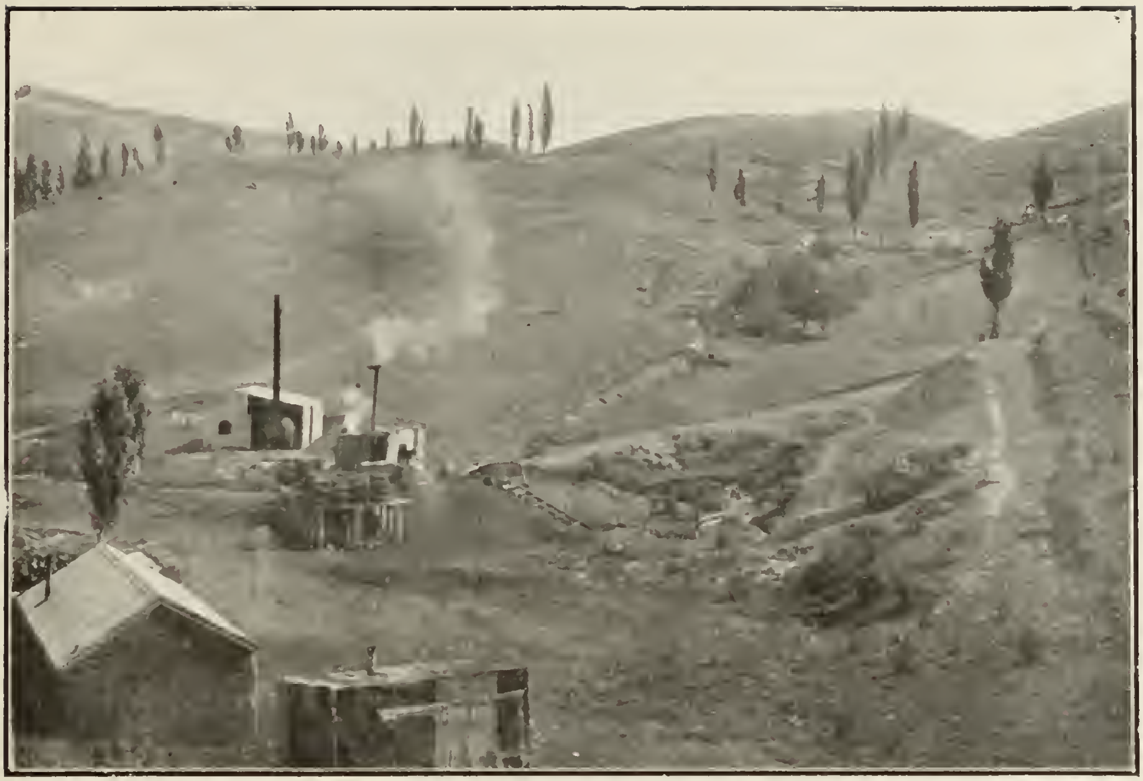
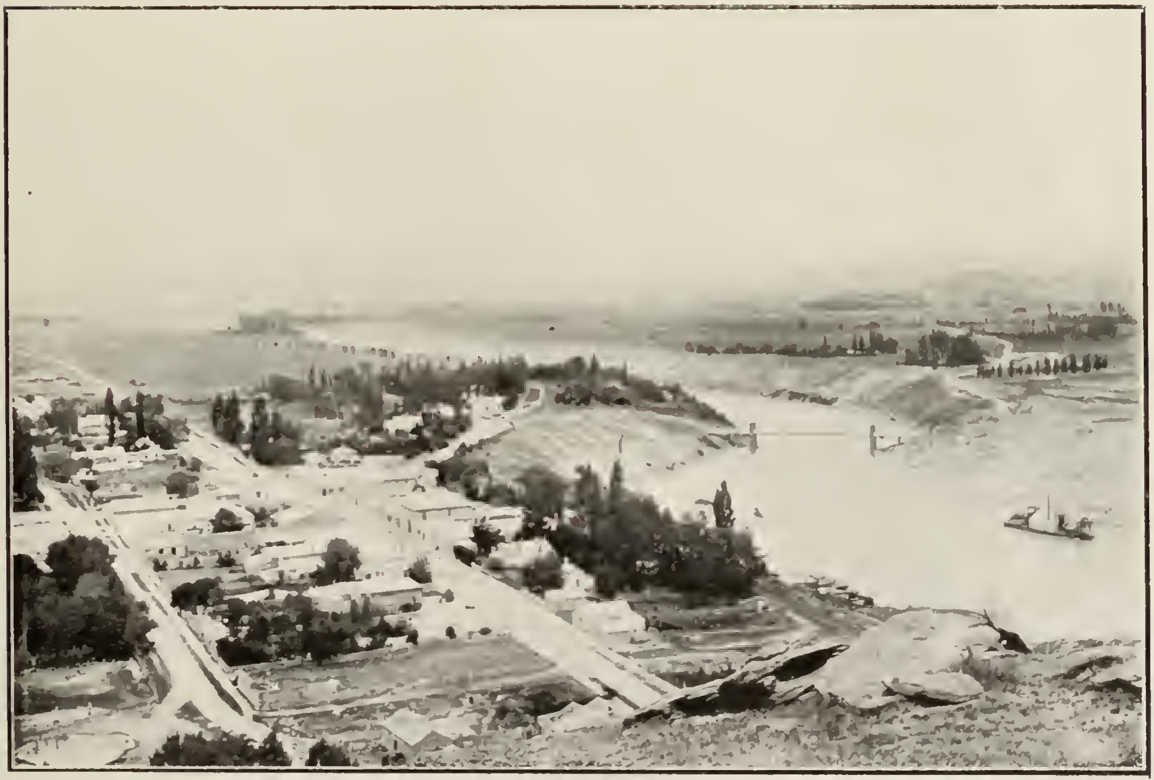
* Calculated from the formula in which evaporative power $= \frac{\text{fixed carbon} \times 13}{100}$.



Dairy Creek Coal-mine, near Clyde.



Clyde, from the Great Moraine.

gorge. The lignite crops out in several places on the bank of the stream which drains the defile. It is much broken and crushed. The strike is east to west (mag.), and the dip south at an angle of 45°. The faults run parallel with the axis of an anticlinal fold in the mica schist.

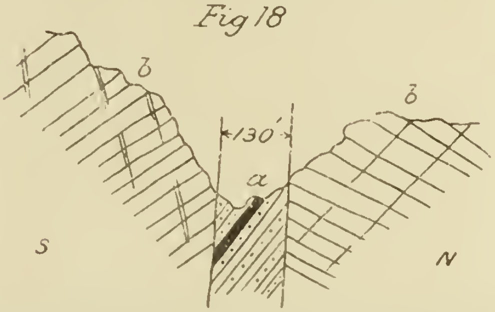


FIG. 18.—SECTION ACROSS UPPER PART OF COAL CREEK.
a. Lignitic series and lignite-seam. *b.* Mica schist.

Alexandra Coal-mine.

This is situated on the bank of the Clutha, near the boundary of the township. The lignite was first discovered cropping out in the face of the terrace. The mine is worked in a systematic manner by the room-and-pillar system. The main roadway starts from the bottom of a vertical shaft some 70 ft. deep. The average thickness of the seam is about 27 ft. The rooms and headings are taken out in the thickness of the coal, there being about 5 ft. underfoot, and from 15 ft. to 20 ft. overhead. The seam is overlain directly by the terrace gravels, the Clutha having at some time prior to the formation of the terrace scoured out the upper beds of the lignite-measures.

Samples of what are termed the "black seam" and "main seam" were submitted to Dr. Maclaurin, who supplied the following analyses:—

	Black Seam.	Main Seam.
Fixed carbon	32·10	23·40
Hydrocarbons	41·30	53·40
Water	20·10	15·10
Ash	6·50	8·10
	100·00	100·00
Evaporative power	4·17 lb.	3·04 lb.

Mathias Mine.

This is situated in the Lower Manuherikia Valley, about a mile from Alexandra. The seam of lignite varies from 8 ft. to 19 ft. 6 in. thick, and is divided into two large seams and one small seam by two thin clay partings. The average thickness is somewhat under 14 ft. The bearing of the line of dip of the seam is 275° (mag.). The inclination near the outcrop is about 1 in 7, and towards the dip 1 in 10.

Very little exact information can be gleaned with regard to the character and thickness of the strata overlying and underlying the seam. Immediately overlying the seam there is a thick deposit of fine sand with bands of sandy clay. This stratum is a member of the lignitic measures, and can be seen in vertical section at the crossing of the Manuherikia on the road to Galloway Flat.

An average sample of the lignite supplied to the market from this mine, as analysed by Mr. H Lovell, has the following composition :—

Fixed carbon	17·38
Hydrocarbons	49·38
Water	25·01
Ash	7·00
Sulphur	1·23
	100·00
Evaporative power	2·26 lb.

Soil.

The soil resulting from the disintegration of the mica schist possesses all the elements of great fertility. But the subsoil is generally porous, the soil itself light, and the rainfall scanty, ranging from some 15 in. in the low land to 25 in. in the uplands. From these circumstances it arises that the plains and terraces for the greater part of the year are bare and desolate, in many places little better than a desert. But, though bare, they are not barren. The soil possesses a latent richness that the casual observer would hardly suspect. By the application of water the wilderness is transformed into fruitful gardens and prosperous farms.

An analysis by Dr. Maclaurin of an average sample of the soil, collected at Alexandra, shows it to be specially adapted for the growth of cereals and root-crops :—

Silica	61·73
Alumina	18·67
Ferric oxide	5·10
Titanium oxide	1·30
Lime	2·85
Magnesia	1·67
Soda (Na_2O)	3·22
Potash (K_2O)	2·57
Water and organic matter	2·52
Undetermined	0·37
	100·00

The conservation and distribution of water for irrigation purposes will in time convert the plains and valleys of Central Otago into one of the most prosperous agricultural districts in New Zealand.

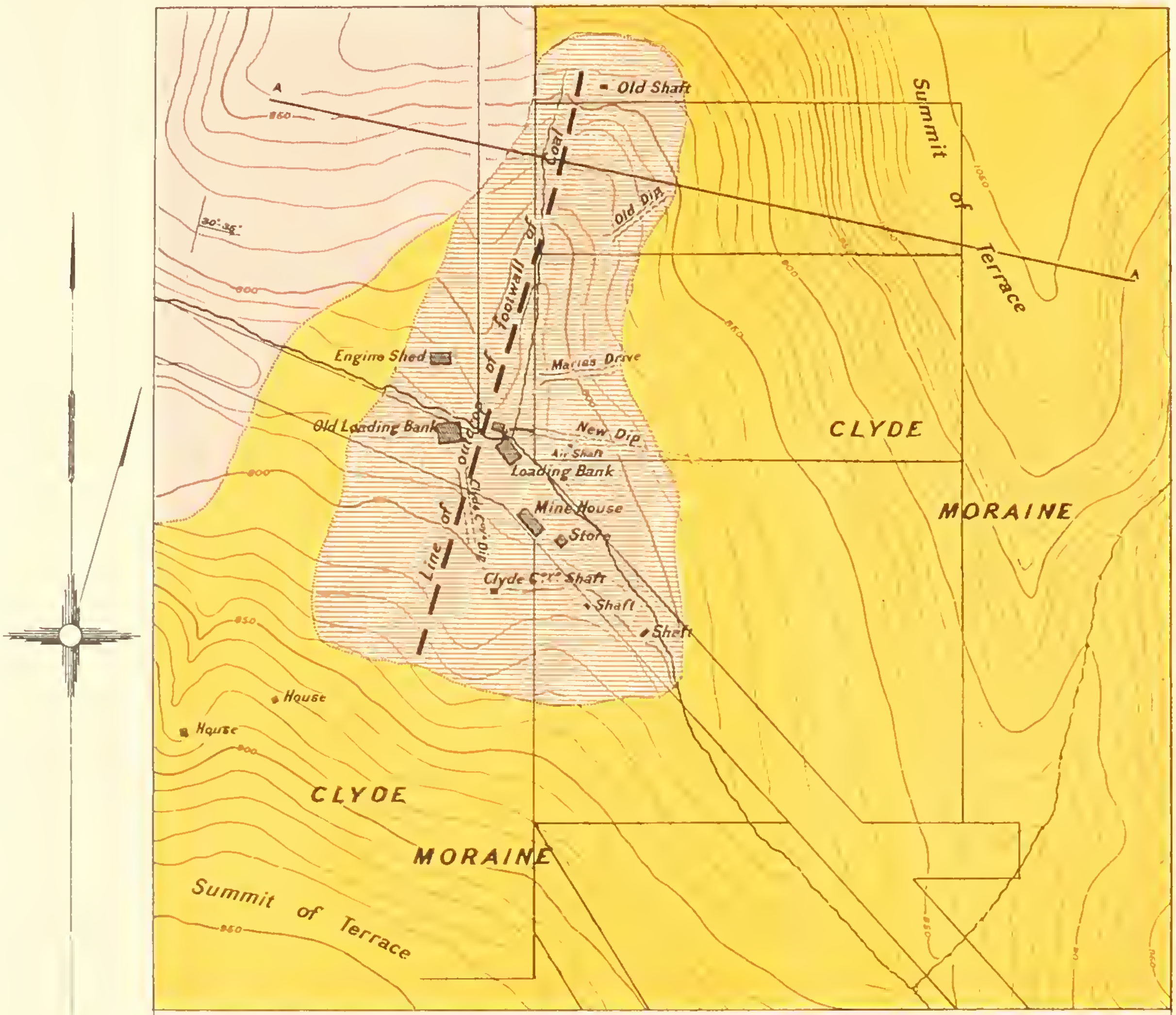
At one time the spurs and mountains were covered with tussock-grass, which was especially luxuriant in the hollows lying between the peculiar hummocks or knobs of rock so characteristic of Central Otago. At Ophir and along the sunny side of Raggedy Ridge, wherever the tussock has been destroyed by persistent burning, the ground is becoming covered with the patch plants *Raoulia australis* and *Raoulia parkii*, which, however beautiful they may be, so effectually cover the ground, as with a carpet, that the growth of grasses or other fodder plants is impossible where they exist.

Climate.

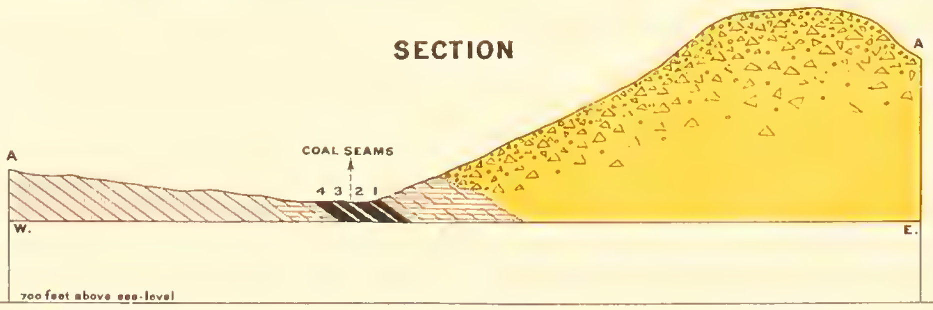
The climate of Central Otago is probably the most salubrious in New Zealand. The summer is sunny, dry, and warm ; the winter, cold, dry, and bracing. The rainfall throughout the year is the lowest in Otago, perhaps the lowest in New Zealand.

To accompany Bulletin N° 2. Alexandra Sheet, Central Otago Division

Geological Map of
DAIRY CREEK COAL AREA
Leaning Rock Survey District.



SECTION



Reference to Geological colours

PLEISTOCENE	PLIOCENE	AGE?
🟨	▤	▨
Glacial Drift	*Clays & Sands* *Coal Measures.*	*Mica Schist*

Geology by James Park.
Topographical data mainly supplied by the Lands and Survey Department, and in part from original surveys by R.A. Farquharson and H.R. Macdonald, under James Park's direction.

Scale of chains

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— CONTOUR INTERVAL : 10 FT —

JAMES MACKINTOSH BELL
Director.

Drawn by G.P. Wilson.

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CHAPTER V.

PETROGRAPHY.

Rocks of Maniototo series .. .. .. Page 41
Igneous rocks in Clutha gravels foreign to Central Otago .. .. Page 46

Rocks of Maniototo Series.

The beautiful micro-photographs with which this chapter is illustrated are the work of Mr. Alexander McKay, F.G.S., Government Geologist, whose unique work in micro-photography is now so well known, and to whom my special thanks are due for his valuable contribution to this division of my report.

No. A1. Mica Schist, Alexandra South.—This is fairly representative of the lower mica schist of Central Otago.

Macroscopic Examination.—Sp. gr., 2·71. A dirty slate-grey rock with marked lamellation of quartz and mica. When viewed in mass it presents a brown or dark-russet appearance on weathered surfaces. The quartz and mica laminæ are often corrugated or wavy.

Microscopic Examination.—The rock consists almost exclusively of quartz and mica arranged in irregular laminæ. Rutile is always present, and often a plagioclase feldspar.

Quartz: In regular broad bands, with the usual optical characters.

Mica: A white sericitic mica, probably muscovite; plentiful in rectangular or elongated plates; birefringence brilliant. Optical characters correspond with those of muscovite.

Plagioclase: Short imperfectly formed crystals of an acid triclinic feldspar, probably albite, are fairly common.

Rutile: This occurs in long thin needles; it is abundant in some parts of the rock. From its high refractive index it appears as dark-brown, almost black, opaque needles.

Analysis.—The following analysis by Dr. Maclaurin, Colonial Government Analyst, shows that the sample of rock under examination contains somewhat less silica and more alumina than the typical mica schist of Otago; the alkalies and lime are about normal:—

	Dr. J. S. Maclaurin
Silica	56·70
Alumina	20·49
Ferric oxide	3·76
Ferrous oxide	2·88
Manganous oxide	0·23
Chromic oxide	Nil.
Lime	3·80
Magnesia	1·89
Titanium-oxide	0·75
Potassium-oxide	3·30
Sodium-oxide	2·85
Sulphuric anhydride (SO	Nil.
Carbon-dioxide	0·27
Water lost below 100° C.	0·37
Water lost above 100°C.	2·66
	99·95

No. A2. Chlorite Schist, Dunstan Mountains, on spur leading up to Leaning Rock.

MACROSCOPIC EXAMINATION.—Sp. gr., 2·89. A pale- to dark-green rock with a silky lustre; very soft and sometimes fibrous; flaggy where laminated with quartz. Often streaked with veins of quartz and studded with grains of magnetite.

MICROSCOPIC EXAMINATION.—In thin slice is seen to consist of chlorite and quartz, with magnetite, rutile, and feldspar as accessory minerals, with epidote and calcite as alteration products.

Quartz: Occurs in small grains flattened in the direction of the foliation. In places forms a quartz-mosaic.

Chlorite: Pale-green in colour, slightly pleochroic; generally in small scales or leaves altered at the margins. Some of the scales are stained with ferric oxide.

Magnetite: Abundant in large and small grains.

Rutile is present, but not common.

Plagioclase probably labradorite: not abundant.

Epidote is abundant; an alteration product of chlorite.

Calcite: Conspicuous iridescence; cleavage pronounced.

Analysis by Dr. Maclaurin.

Silica	42·97
Alumina	16·06
Ferric oxide	7·92
Ferrous oxide	6·05
Manganous oxide	0·45
Chromic oxide	Nil.
Lime	11·45
Magnesia	3·24
Titanium-oxide	2·75
Potassium-oxide	0·90
Sodium-oxide	2·64
Sulphuric anhydride (SO_3)	0·16
Carbon-dioxide	3·45
Water lost below 100° C.	0·05
Water lost above 100° C.	1·28
	99·37

The high percentage of lime is unusual, and would tend to indicate a greater abundance of feldspar in the unaltered schist than appears in the samples selected from surface outcrops.

No. A3. Red Micaceous Quartz Schist.—This beautiful rock is interbedded in the chloritoid mica schist on the spur leading from the Halfway House in Dunstan Gorge to Leaning Rock, at an altitude of 3,200ft. above the sea. It is abundant in the form of large angular masses in the glacier drifts of Clyde moraine, being especially noticeable on the terrace road from Clyde to Dairy Creek Colliery. Many angular masses are also scattered through the glacier drift lying between Waikerikeri and Springvale. Small rounded boulders and pebbles are present but not abundant in the terrace gravels along the course of the Clutha from Clyde to Alexandra.

MACROSCOPIC EXAMINATION.—Sp. gr., 2·68. A fine-grained micaceous quartz schist consisting of distinct bands of quartz and a red micaceous mineral, the former being much thicker than the latter. The rock splits readily along the foliation-planes, and on the longitudinal surfaces thus exposed shows brilliant reflection from innumerable rose-pink spangles.

Microscopic Examination.—The rock when examined in thin slice is seen to consist almost exclusively of quartz and a red mica. A little rutile and magnetite are present.

Quartz : This occurs in large and small grains arranged in regular bands and often elongated in the direction of the foliation ; often contains fluid cavities.

Mica : This mineral is pleochroic ; colour, red to faint-pink or light-brown ; in the longitudinal sections the birefringence is brilliant. crystals long acicular prisms often with the wavy appearance seen in micas subjected to a crushing stress. Sections—that is, slices—cut transversely to the foliation-plane show that the optical characters of the mineral do not quite agree with those of lepidolite given by Rosenbusch. When viewed in longitudinal section the agreement with lepidolite is closer, but not complete, and the absence of lithia in the rock, as shown by Dr. Maclaurin's analysis, throws the mineral outside lepidolite. The agreement with phlogopite is no closer. The analysis quoted below would indicate that we are dealing with a mica somewhere between lepidolite and phlogopite, in which the lithia of the former is replaced by manganese.

Analysis by Dr. Maclaurin.

Silica	89·86
Alumina	2·71
Ferric oxide	0·40
Ferrous oxide	2·66
Manganese oxide	1·02
Chromic oxide	Nil.
Lime	0·10
Magnesia	0·96
Titanium-oxide	0·78
Potassium-oxide	0·26
Sodium-oxide	0·56
Sulphuric anhydride (SO_3)	0·13
Carbon-dioxide	Nil.
Water lost below 100° C.	0·05
Water lost above 100° C.	0·22
	99·71

Remark.—This rock contains no lithia.

Illustration.—This rock is shown as photographed by ordinary and by polarised light. The quartz-mosaic is well developed in the photograph taken between crossed nicols.

No. 4. Micaceous Quartz Schist, from Green's Reef workings. Ophir.—This rock follows the chlorite schist both on Old Man and Raggedy Ranges and Dunstan Mountains. The junction between the two is generally not well marked. the quartz schist being intercalated with the chlorite schist in thin irregular bands for some feet thick. The quartz schist decomposes at the surface into loose grey quartz sands mixed with a grey talcose clay.

Macroscopic Examination.—Sp. gr., 2·58. Greyish-white, fracture splintery, fissile. No mineral but quartz visible to the naked eye.

Microscopic Examination.—In thin slice the rock is seen to consist chiefly of quartz with a subordinate amount of mica and feldspar. A few small crystals of garnet are also present. The analysis would indicate the presence of rutile, but none was seen.

Quartz : This mineral occurs in medium-sized grains elongated in the direction of the foliation-plane. Some of the grains contain fluid inclusions.

Mica : This is white, and in transverse section appears as thin wavy lines with no decided optical characters. It is a sericitic mica, and probably includes both muscovite and paragonite.

Plagioclase : This occurs in the matrix, but is not well defined. It is probably albite.

Analysis by Dr. Maclaurin.

Silica	72·80
Alumina	16·03
Ferric oxide	1·20
Ferrous oxide	1·15
Manganese oxide	0·21
Chromic oxide	Nil.
Lime	0·11
Magnesia	0·81
Titanium-oxide	0·25
Potassium-oxide	2·54
Sodium-oxide	2·84
Sulphuric anhydride (SO_3)	0·24
Carbon-dioxide	Nil.
Water lost below 100° C.	0·29
Water lost above 100° C.	1·83
	100·30

Illustration.—This slice was photographed both in ordinary and polarised light. The wavy lines of mica are well seen in ordinary light, and the quartz-mosaic in polarised.

No. A5. Mica Schist, from upper part of lower schists at Alexandra South.—This rock is somewhat more quartzose than the average mica schist of this district.

Macroscopic Examination.—Sp. gr., 2·70. Consists of alternating bands of quartz and white mica, the former predominating.

Microscopic Examination.—In thin slice the rock is seen to be composed of quartz and mica arranged in more or less distinct and continuous laminæ.

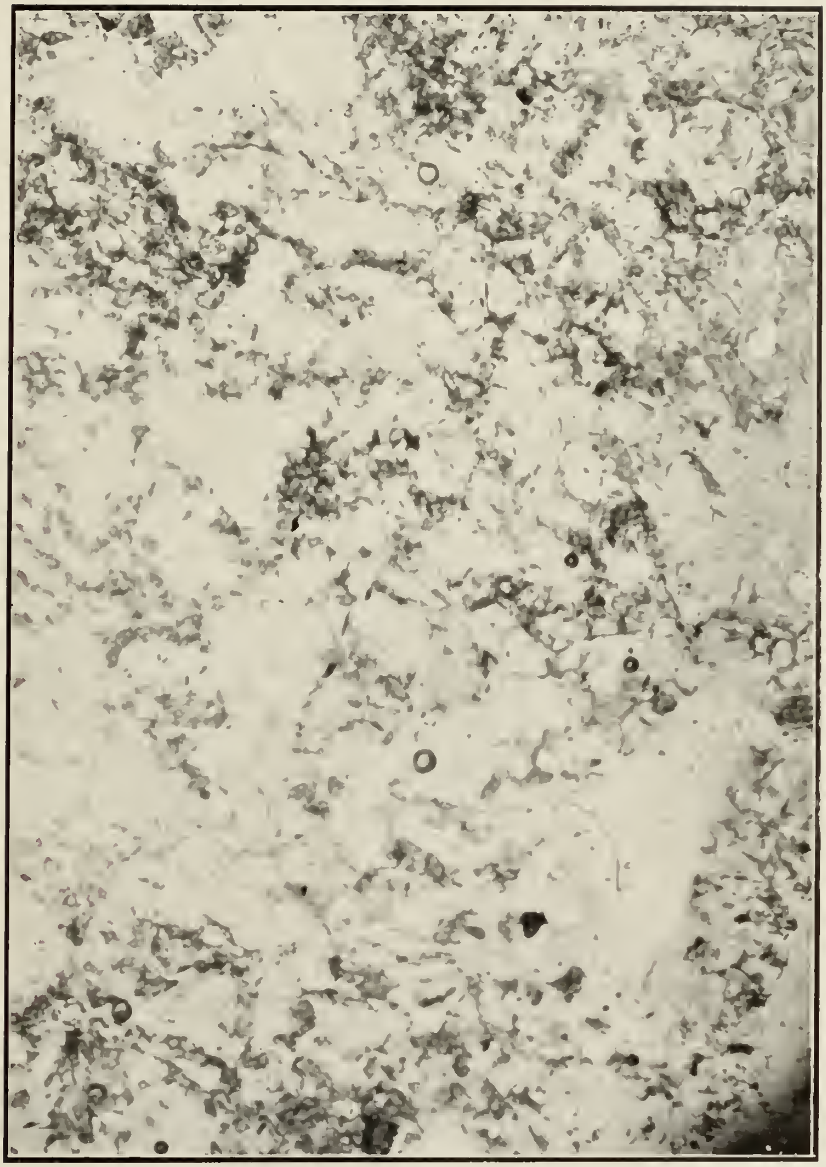
Quartz : Occurs in bands forming a quartz-mosaic, the elongation of grains being parallel with the foliation-plane.

Mica : Occurs in long thin crystals, highly birefringent, and almost colourless. It is probably muscovite.

Rutile is present, but not common.

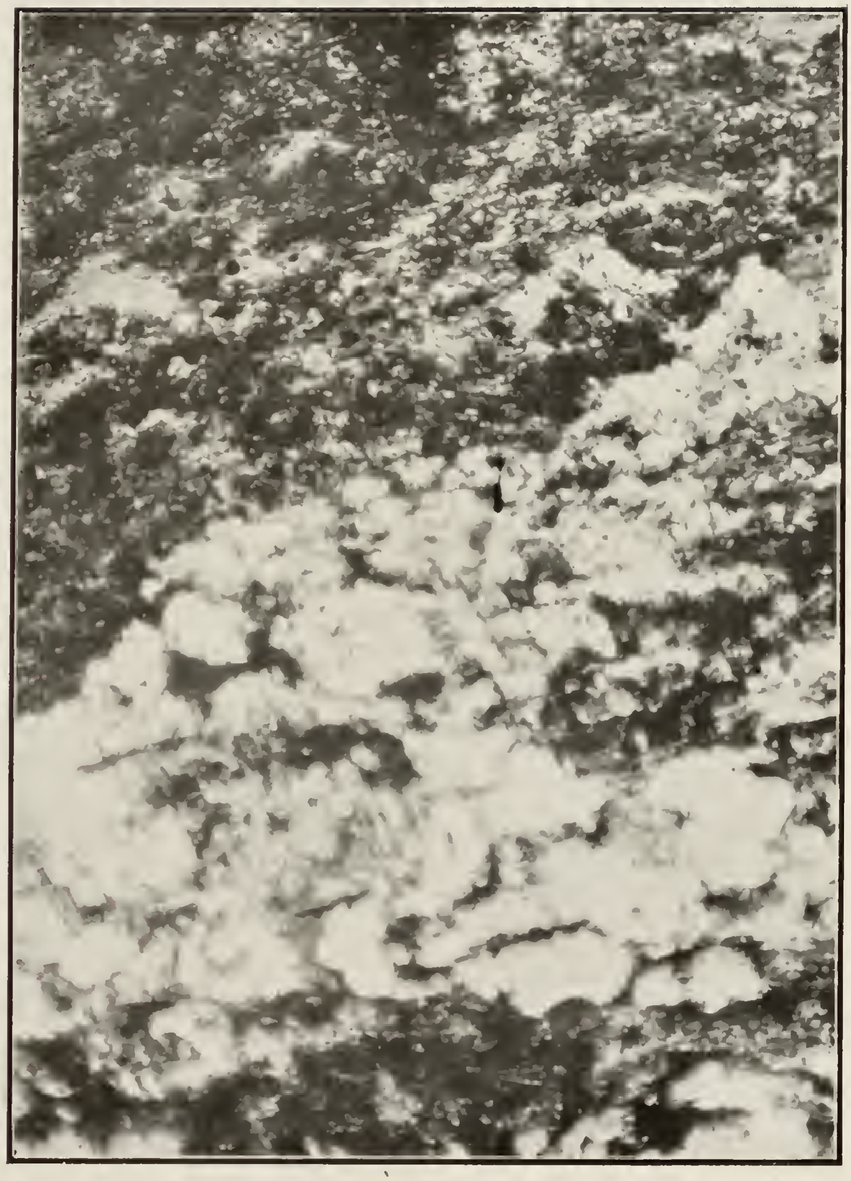
Analysis.—Two analyses of mica schist from Macrae's, by Mr. A. M. Finlayson, B.Sc., are tabulated with that of Dr. Maclaurin for purposes of comparison :—

	A5.	M1.	M2.
Silica	67·70	66·65	67·28
Alumina	16·82	11·25	11·71
Ferric oxide	2·00	1·81	2·21
Ferrous oxide	1·94	3·92	3·75
Manganese oxide	0·37	3·05	2·67
Chromic oxide	Nil	..	..
Lime	2·10	5·97	5·31
Magnesia	0·30	1·15	1·27
Titanium-oxide	0·42	Traces	Traces.
Potassium-oxide	4·11	1·77	1·69
Sodium-oxide	2·38	2·38	2·67



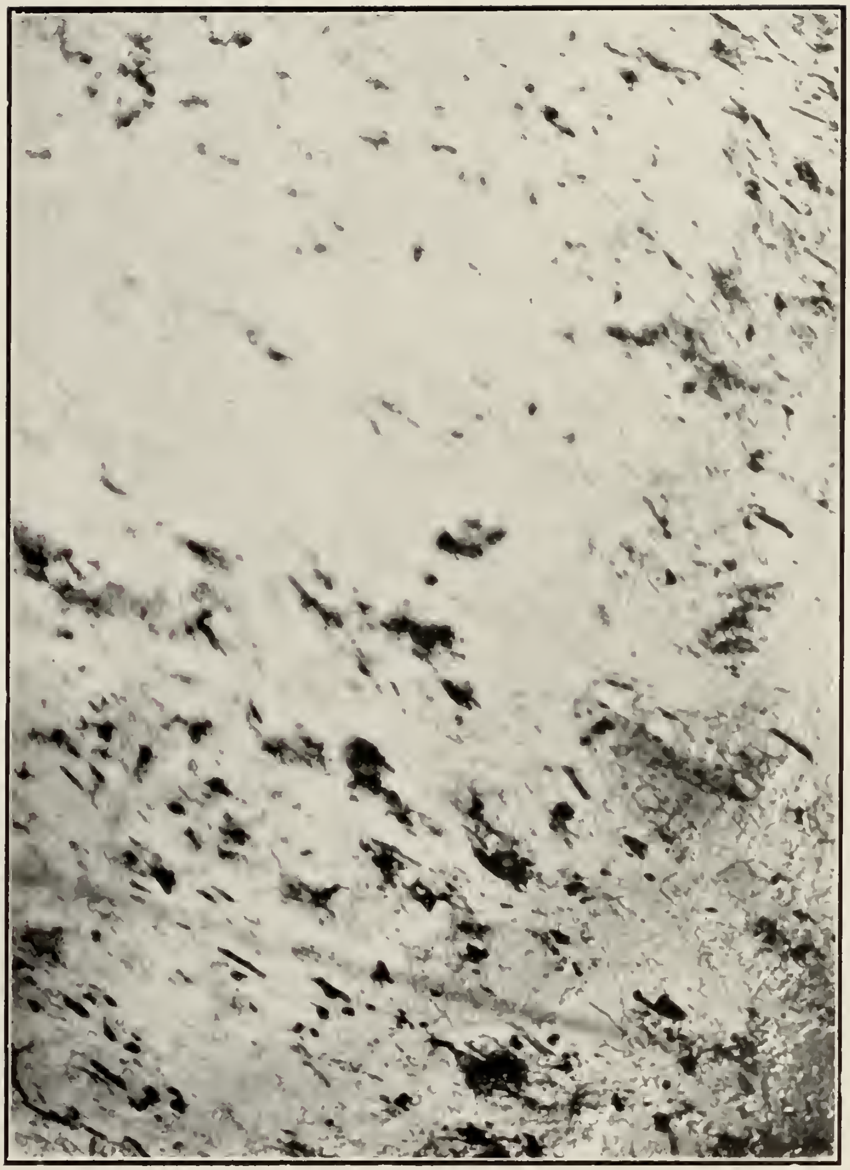
No. A 1. MICA SCHIST.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



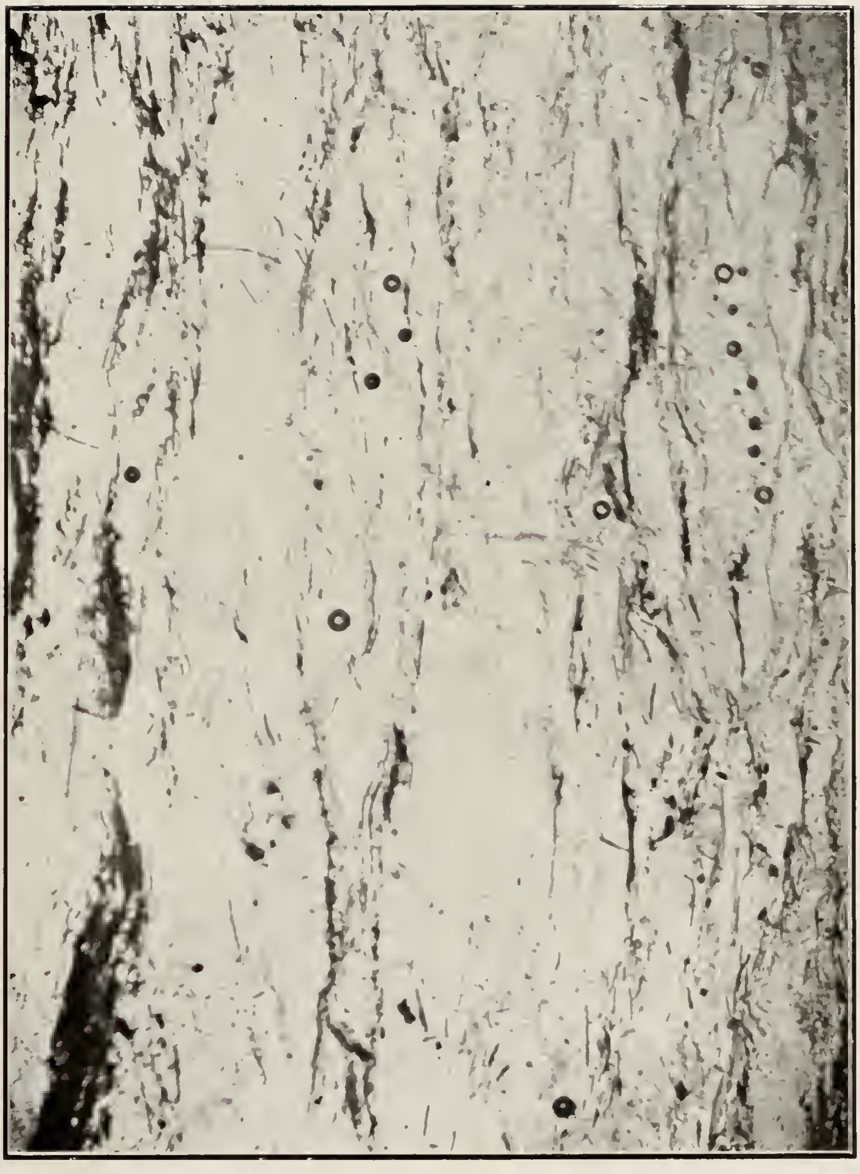
No. A 2. Chlorite Schist.

Ordinary light: magnification, 34. *Photo. by A. McKay.*



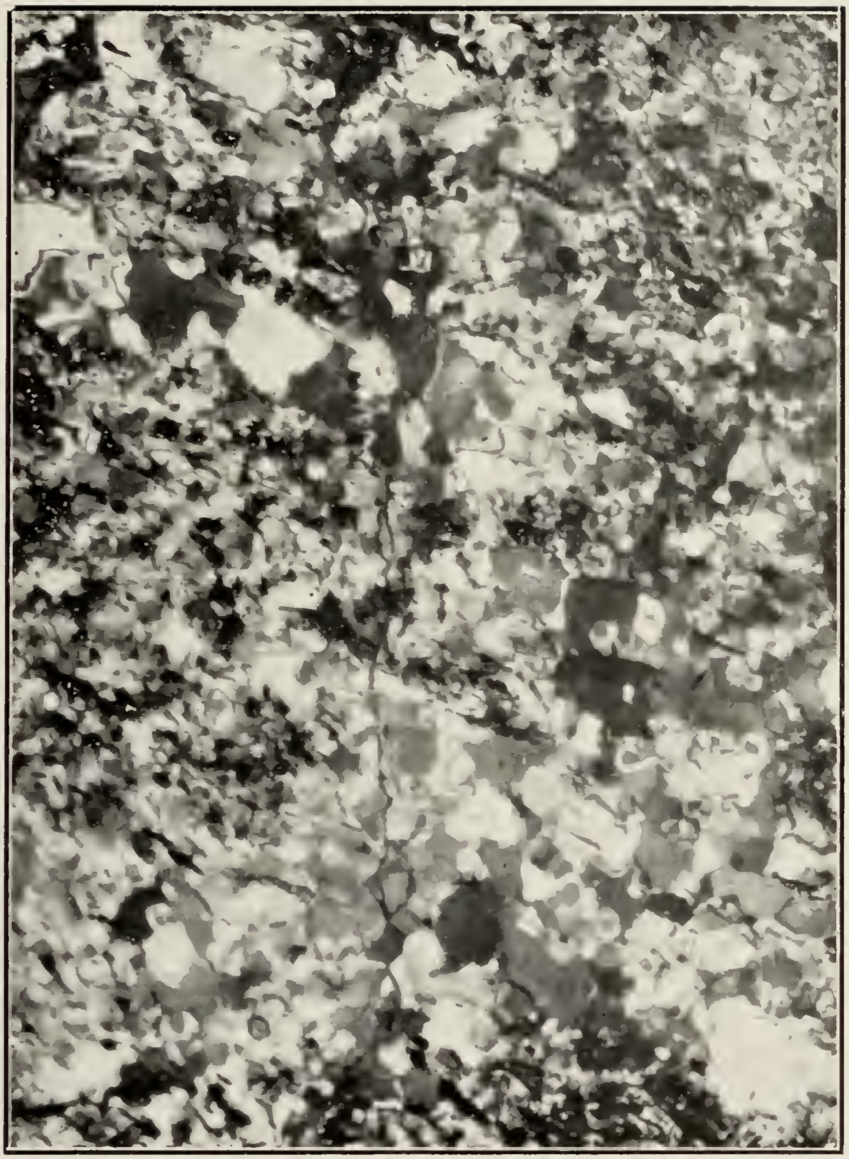
No. A 3. RED MICACEOUS QUARTZ SCHIST.

Slice parallel to foliation; ordinary light; magnification, 34. *Photo. by A. McKay.*



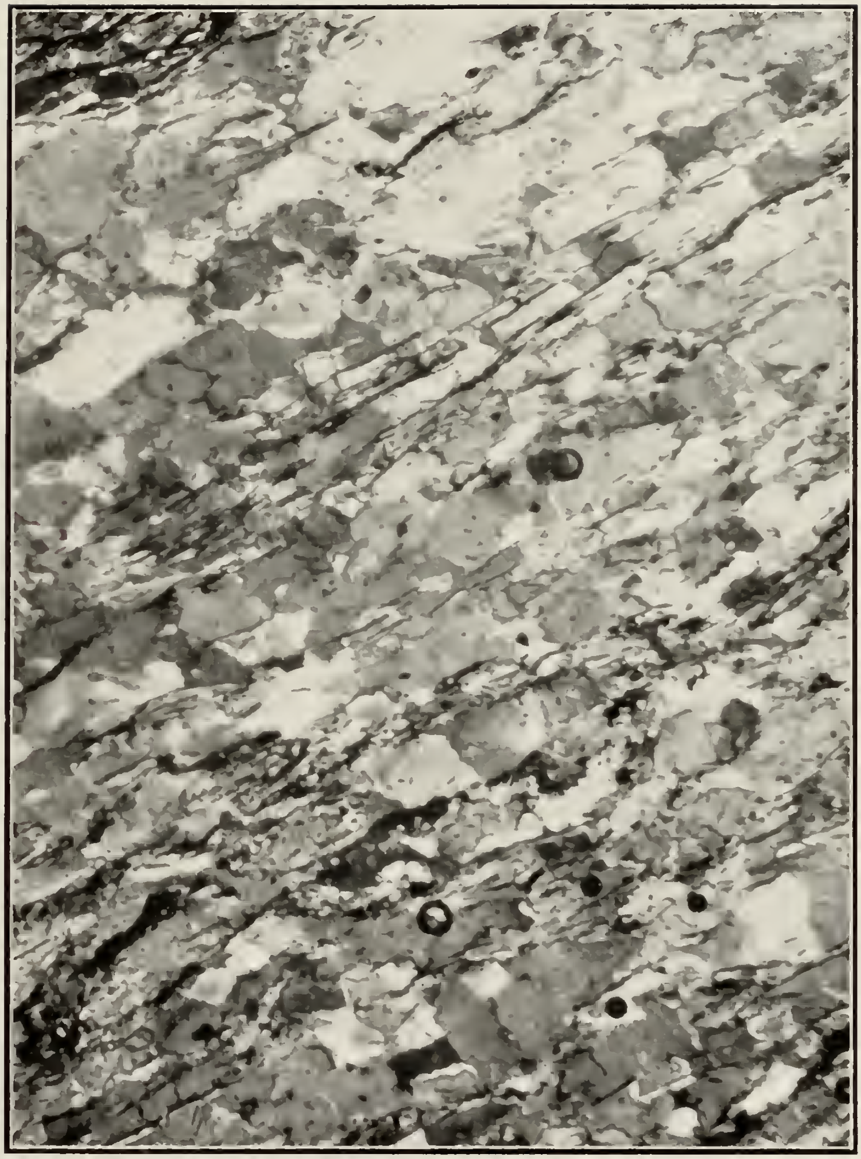
No. A 3. RED MICACEOUS QUARTZ SCHIST.

Slice transverse to foliation; ordinary light; magnification, 34. *Photo. by A. McKay.*



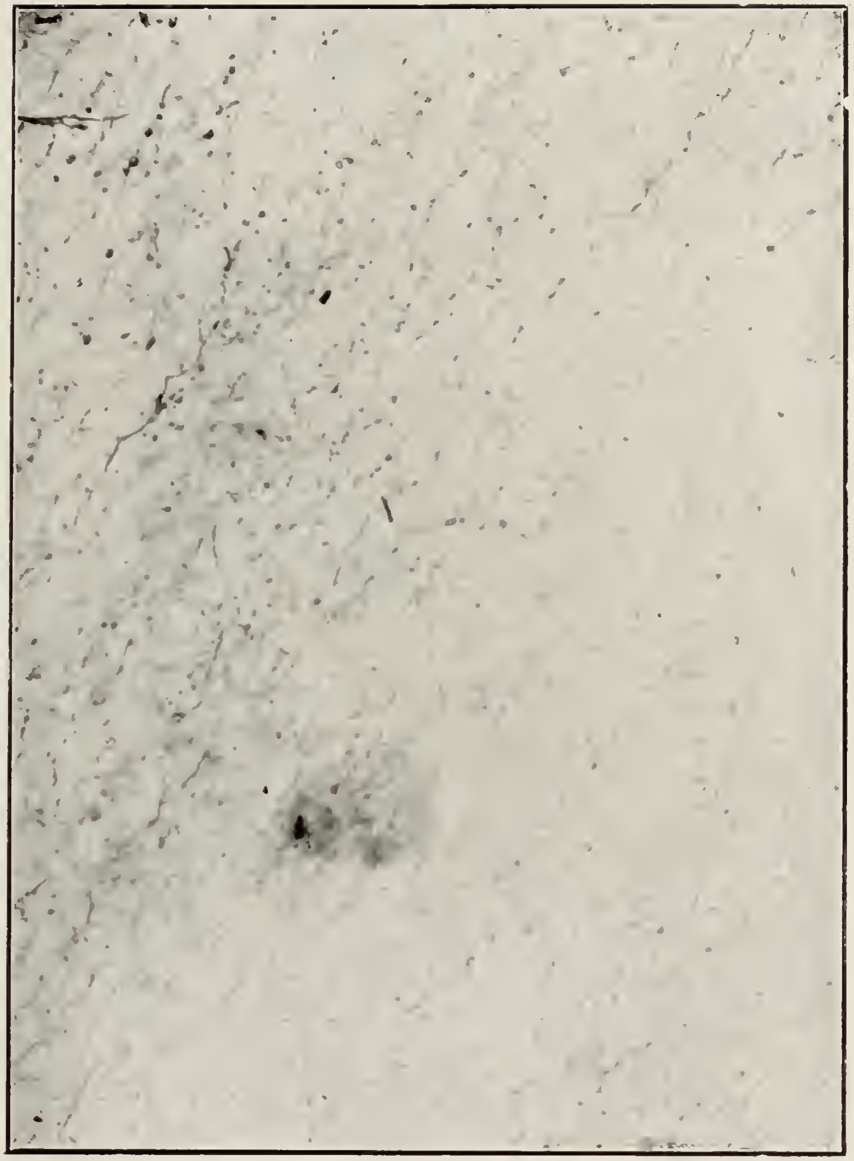
No. A 3. Red Micaceous Quartz Schist.

Section parallel to foliation; polarised light; magnification, 34. *Photo. by A. McKay.*



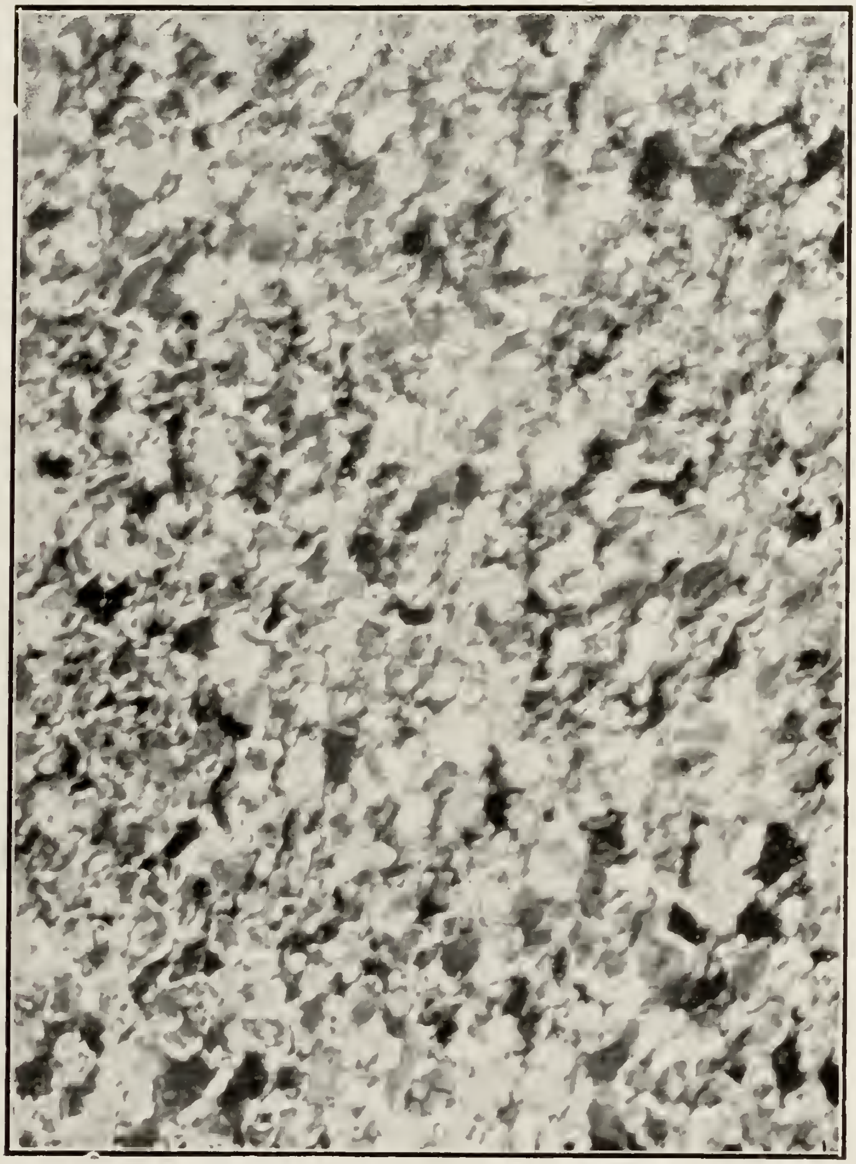
No. A 3. Red Micaceous Quartz Schist.

Section transverse to foliation; polarised light; magnification, 34. *Photo. by A. McKay.*



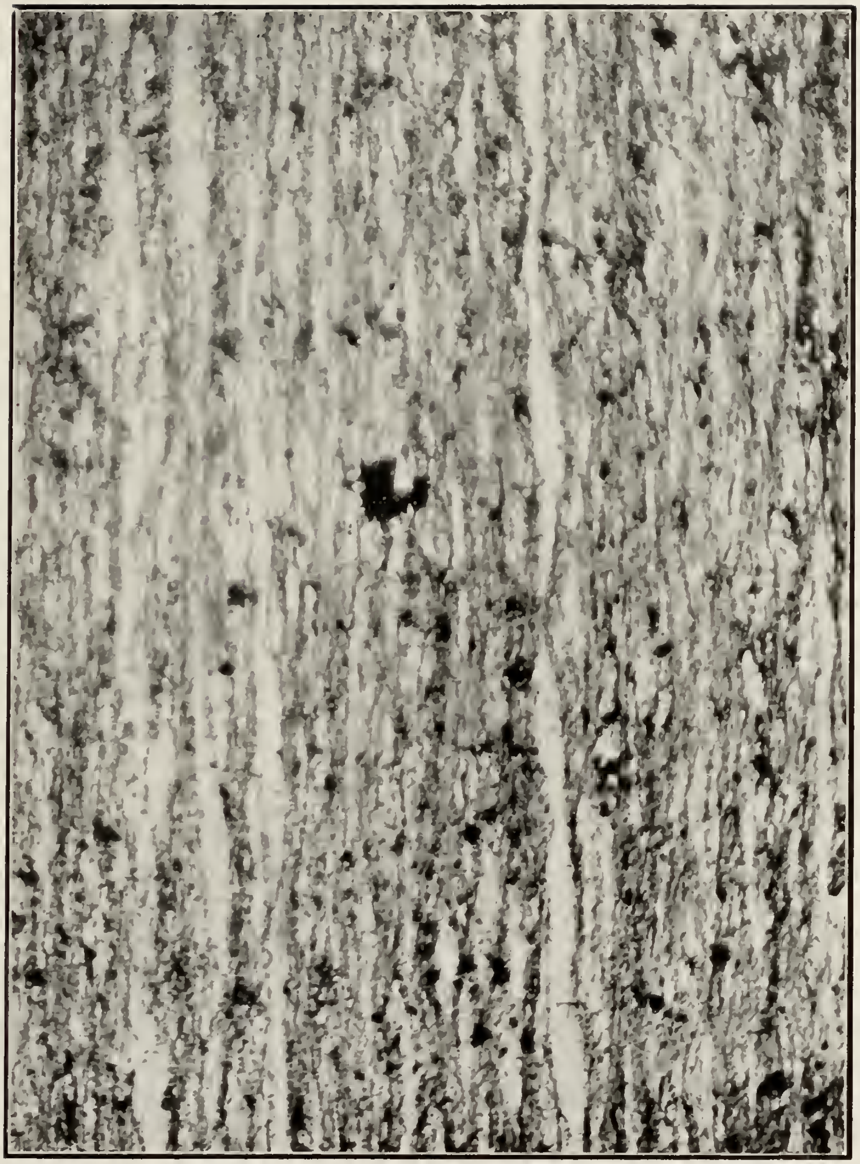
No. 4. MICACEOUS QUARTZ SCHIST.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



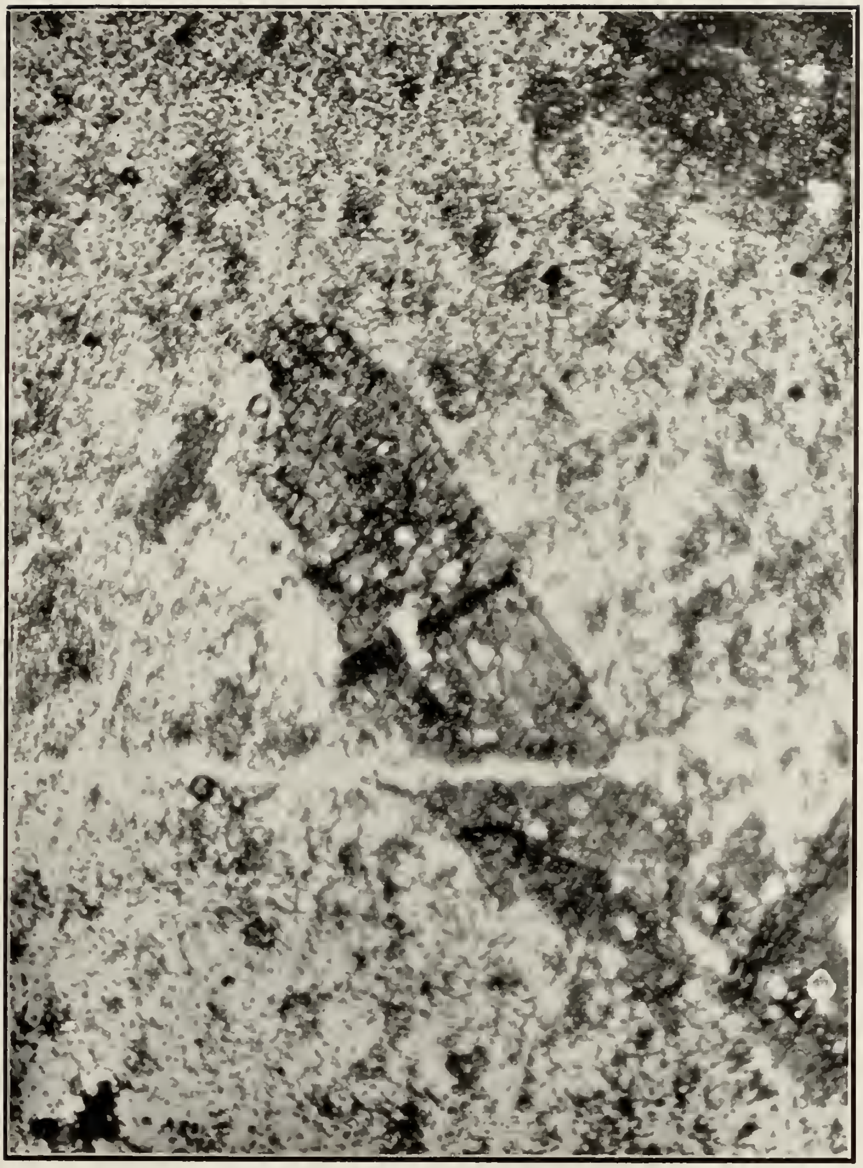
No. 4. MICACEOUS QUARTZ SCHIST.

Polarised light; magnification, 34. *Photo. by A. McKay.*



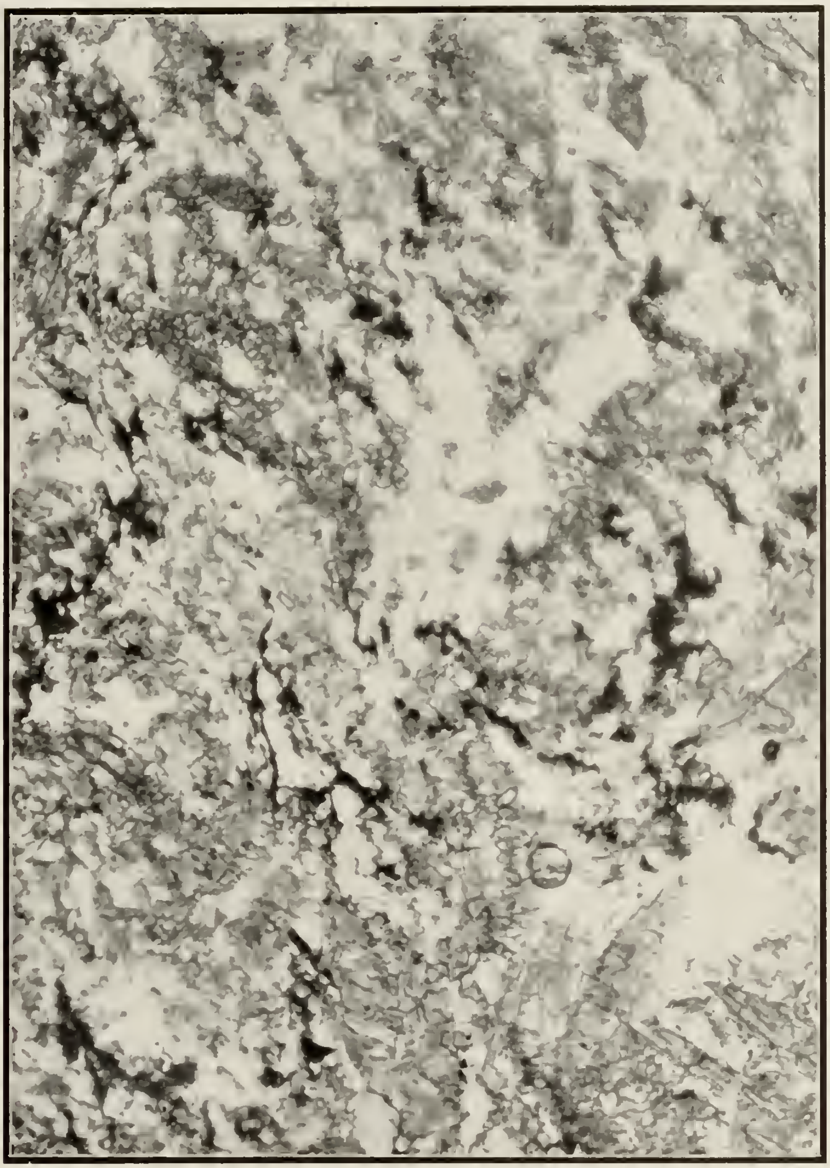
No. A 5. Mica Schist.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



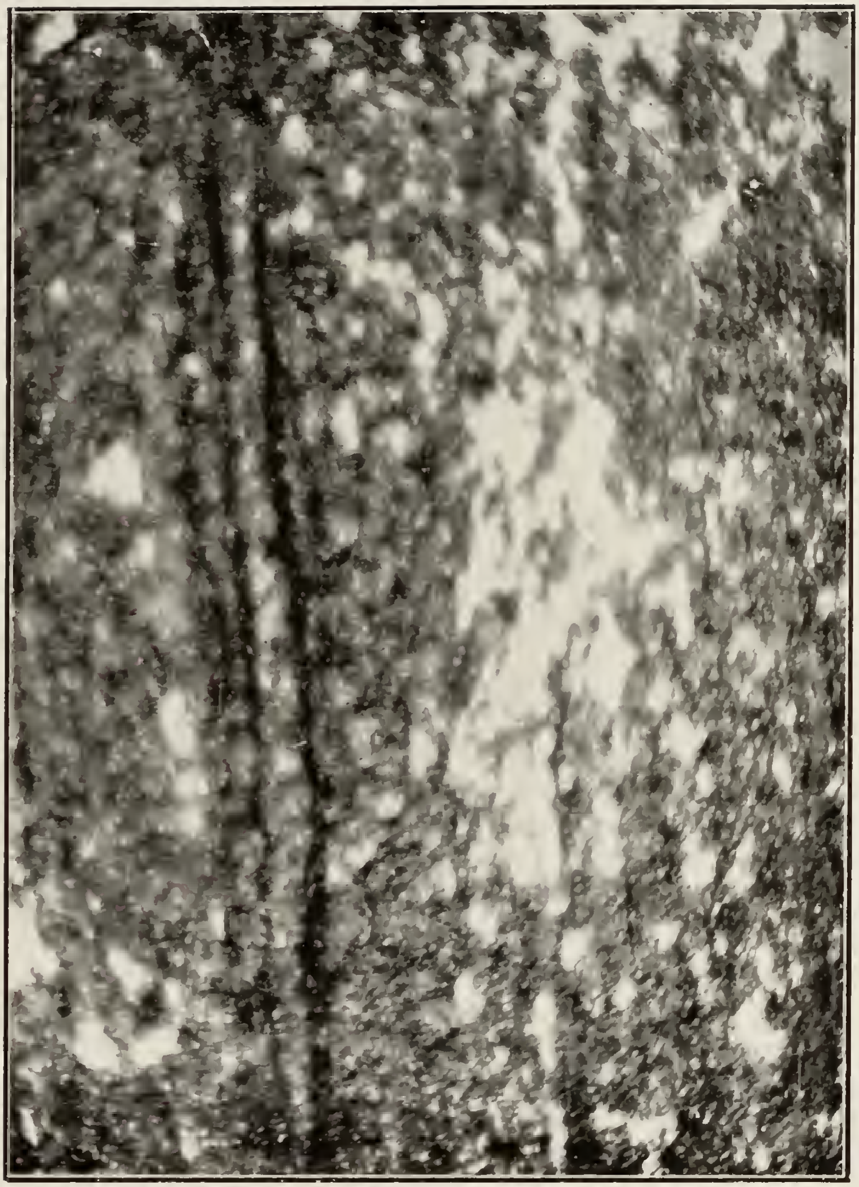
No. A 9. Quartz Schist, with Actinolite and Garnets.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



No. 2. Actinolite Schist.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



No. O 6. CHLORITE SCHIST WITH EPIDOTE.

Ordinary light; magnification, 34. *Photo. by A. McKay.*

	A5.	M1.	M2.
Sulphuric anhydride (SO_3)	0·27	..	..
Carbon-dioxide	0·25	..	..
Water lost below 100° C.	0·20	1·29	0·97
Water lost above 100° C.	1·70	1·34	1·35
	100·56	100·58	100·88

No. A9. Quartz Schist, with actinolite sheaves.—This rock occurs at the extreme head of Waikerikeri Creek, at the upper end of Lillico Spur.

Macroscopic Examination.—Sp. gr., 2·83. Colour, cream or yellowish-grey; very fissile, splitting readily into thin plates; feathery sheaf-like aggregates of green actinolite are spotted throughout the rock, in all cases occurring along the cleavage-planes.

Microscopic Examination.—In thin section the rock is seen to consist of a mosaic of quartz-grains, actinolite, and innumerable minute crystals of garnet.

Quartz: In small grains, generally elongated in a direction parallel with the foliation-plane.

Actinolite: Occurs in large elongated crystals; extremely fibrous, with peculiar cross-cleavage; strong pleochroism, ranging from yellow to green and blue. The crystals are studded all over with small garnets.

Garnet: The whole rock is thickly studded with minute colourless garnets which sometimes form denser clusters. The form is regular, chiefly the dodecahedron and cube. Almost isotropic, with high refractive index.

Illustration.—Taken in ordinary light. The photograph shows the large crystal of actinolite near the centre of the plate, and numerous small garnets scattered all over it.

No. 2. Actinolite Schist.—Sp. gr., 3·11. This rock is exposed along the truncated crown of a sharp anticline near Ophir.

Macroscopic Examination.—Sp. gr., 2·80. A dark-greyish-green rock; very dense and compact; tough; schistose structure but feebly developed. In hand-specimens appears to be composed of quartz and actinolite.

Microscopic Examination.—*Actinolitic hornblende* occurs in long needle-shaped crystals in great numbers; much cross-jointed; extinction angle high for hornblende; pleochroism noticeable, from bluish-green to yellow. The crystals show no definite terminations. In places decomposed to serpentine with separation of magnetite.

Quartz: This occurs as small grains scattered irregularly throughout the rock.

Epidote: Occurs to a small extent; yellowish in colour, with slight pleochroism.

Rutile is present but not common.

Analysis by J. E. Menzies.

Silica	46·80
Alumina	19·20
Ferric oxide	3·62
Ferrous oxide	7·43
Titanium-oxide	Traces.
Potassium-oxide	Traces.
Sodium-oxide	1·13
Lime	9·08
Magnesia	8·72
Combined water	4·50
	100·48

ILLUSTRATION.—Taken in ordinary light. The actinolite and quartz-mosaics are very clearly developed in this section.

No. O6. Chlorite schist, with epidote.—This rock is interbedded with the mica schist forming the foothills immediately behind Ophir.

MACROSCOPIC EXAMINATION.—Sp. gr., 3·19. A soft close-grained rock, except where the chlorite is epidotised. Exhibits a fairly well-developed schistose structure. Pale to dark green in colour. The rock is mainly composed of chlorite, but epidote can often be recognised by the naked eye.

MICROSCOPIC EXAMINATION.—The chief constituents are chlorite, epidote, and quartz, arranged in more or less irregular bands. Rutile and magnetite are also present.

Quartz : This mineral is scarce, and occurs in small grains.

Chlorite : Plentiful, occurring in irregularly shaped crystals altered and eroded at the margins ; strongly pleochroic, from yellow to bluish-green ; birefringence high.

Epidote : This mineral occurs in thin bands of closely aggregated crystals ; very dense ; colour yellow with slight pleochroism ; no cleavage discernable ; refractive index high, with conspicuous birefringence. Epidote as short blunt crystals also occurs throughout the chlorite.

Rutile : Occurs in small very dark crystals of high birefringence.

Magnetite is not common ; it occurs in small grains.

IGNEOUS ROCKS IN CLUTHA GRAVELS FOREIGN TO CENTRAL OTAGO.

No. C3. Olivine basalt (smooth)—This rock is abundant in the glacier drifts, forming the high terraced lands behind Clyde. It is found, but less abundantly, in the re-sorted glacier drifts and river-gravels between Clyde and Alexandra. Sometimes called " Black Maori " by the local alluvial miners.

MACROSCOPIC EXAMINATION.—Sp. gr., 3·04. A heavy close-grained black rock. Very hard and tough.

MICROSCOPIC EXAMINATION. — Sp. gr., 3·04. In thin slice the rock is seen to be composed of feldspar, augite, and olivine, with some apatite and magnetite.

Plagioclase : No distinct phenocrysts are present, the feldspar occurring only as long narrow lath-shaped microlites, which are not abundant. A few of the larger crystals show albite lamellation, but the majority are too small to show this.

Augite : No phenocrysts are present, the mineral occurring only in one generation of crystals in the groundmass, in which it is abundant as small idiomorphic prisms, brownish in colour, and possessing the usual high refractive index and birefringence. Augite is the most common constituent in the groundmass.

Olivine : Fairly common in small imperfectly shaped crystals ; colourless ; often decomposed into serpentinous matter, especially around the margins and along the cracks that cross the crystals ; the reddish-brown colour of the decomposition products is due to the alteration of the iron from the protoxide to the peroxide ; regularly bounded phenocrysts appear to be absent or very rare.

Apatite : This mineral occurs in long thin colourless needles with the usual weak birefringence, cross-jointing, and characteristic inclusions.

Magnetite : Very abundant in large and small grains.

Structure : This rock belongs to the holocrystalline class of basalts, there being apparently no glassy residue. The augite, together with the magnetite, makes up by far the greater part of the base, the feldspars being squeezed in between the augite crystals. In one or two sections there are what appear to be decomposition products of olivine showing decided radial extinction ; and frequently a large amount of chloritic material with very slight pleochroism is penetrated by feldspar crystals. Some approach to the hyalopilitic structure observed in some of the andesites of the Hauraki Goldfields is seen, but the microlites of feldspar are not sufficiently numerous.

No. C7. Olivine basalt (pitmarked).—This rock is fairly abundant in the Pleistocene glacier *débris,* and in the gravels of the Clutha below Clyde.

Macroscopic Examination.—Sp. gr., 3·04. In hand-specimens the rock is almost black, dense and fine-grained. The outside skin of the pebbles is marked with peculiar pits or dents, which seem to be quite distinctive of this rock. The constituent crystals are nearly all of the same size, but here and there a cleavage-surface of an augite crystal larger than the others is seen by the unaided eye.

Microscopic Examination.—The constituent minerals are plagioclase, feldspar, augite, olivine, and magnetite.

Plagioclase : No phenocrysts exist. The mineral occurs wholly in the form of small fibrous microlites, very few in number, and usually too thin to show any lamellar twinning.

Augite : This mineral occurs distinctly in two generations. The phenocrysts are large with regular boundaries, as seen in the illustration ; zonary banding very pronounced ; twinning frequent, but no repeated twinning was seen ; colour, brownish to pink : all the larger crystals showed signs of decomposition beginning at the centre, while often the margins are quite intact. The second generation consists of innumerable small prisms of augite, very thin, brown or pink in colour, giving the section a decidedly brown appearance without crossed nicols : decomposition products rare, the augite having evidently resisted any weathering action up to the present.

Olivine : In large rectangular crystals with regular boundaries, or in large grains. Decomposition products plentiful, serpentinous matter showing along the cracks and around the margin. Very abundant ; high refractive index ; pronounced birefringence ; colourless. Not much stained with iron.

Magnetite : Very abundant in small grains or crystals.

Structure : The rock belongs to the holocrystalline class of basalts. The augite crystals make up along with the magnetite the greater part of the base. The feldspar crystals are squeezed in between the augites, showing that the augite has crystallized out first. No pilotaxitic or other structure noticeable.

No. C13. Monchiquite.—This rock occurs as small pebbles in the gravels of the Clutha. It can be traced right back to the Queenstown moraine.

Macroscopic Examination.—Sp. gr., 3·00. A dark, almost black, rock with a dull fracture ; very close-grained, and showing no phenocrysts to the naked eye. Here and there, however, are seen small white specks which the microscope shows to be feldspar.

Microscopic Examination.—The constituent minerals are plagioclase and hornblende, with which occur a little apatite and a good deal of secondary calcite and magnetite.

Hornblende : The section is crowded with short stumpy prisms of brown hornblende exhibiting very marked pleochroism. Many of the crystals taper at the end, giving them a cigar-shaped termination, a feature noticeable in many monchiquites. Alteration products plentiful, chiefly a chloritic substance stained yellow or greenish by iron-oxides.

Plagioclase : Not seen as phenocrysts in any of the slices examined ; occurs as small plates of irregular shape, usually much decomposed, with production of calcite and kaolin. The feldspars are frequently sheaf-like in their grouping, but the crystals are not sufficiently well preserved to show any degree of plagioclase twinning, but some albite twinning is seen. In some slices no feldspar can be recognised at all, the rock consisting only of hornblende prisms and decomposition products such as calcite and magnetite. No analcite was recognised with certainty.

Apatite : This mineral is abundant in long thin needles.

Calcite : This is abundant in the more decomposed parts of the rock. It generally shows pronounced rhombohedral cleavage ; iridescent.

Magnetite : Abundant in some sections.

Remarks.—This rock belongs to that peculiar group of rocks, the lamprophyres, which contain a large percentage of alkalies, a small percentage of silica, and a very large proportion of ferro-magnesian silicate. It is a rock very liable to decomposition, and as much as 30 per cent. of decomposition products have been seen in typical monchiquites. The hornblende crystals are very prominent and often of large size. The feldspars do not seem to occur at all as phenocrysts. No glassy base is noticeable. The occasional presence of very minute prisms of hornblende would tend to indicate two generations, as has been observed in some monchiquites elsewhere.

No. C8. Camptonite.—This rock is found as small well-rounded pebbles in the gravels of the Clutha River. It is somewhat rare.

Macroscopic Examination.—Sp. gr., 2·90. A dark-brownish-black rock studded with very regular black crystals of hornblende. The phenocrysts of hornblende stand out against the apparently homogeneous base with great clearness; and since they are all of the same size and shape they give the rock a somewhat remarkable appearance.

Microscopic Examination.—A holocrystalline aggregate of which the essential constituents are plagioclase and hornblende, with apatite and magnetite as accessory minerals. Calcite, as a decomposition product of the feldspar, is also present.

Plagioclase: Occurs in fairly large phenocrysts showing well-marked lamellar twinning, chiefly after albite law. The mineral is mostly labradorite. The phenocrysts, however, have such an absence of regular outlines that they are very similar to the allotriomorphic plates observed in some diorites. Decomposition is very pronounced; most of the feldspar crystals have been attacked and are partly or wholly represented by a cloudy aggregate of calcite and kaolin.

Hornblende: This mineral is very abundant in large phenocrysts; deep-brown in colour, with well-developed outlines; shape, hexagonal or sometimes rectangular; pleochroism very pronounced, deep-brown to light-brown or almost colourless; cleavage well marked, the two intersecting sets being well shown in the hexagonal sections; decomposition very common, to a product stained yellow with ferric oxide; a slight bleaching is noticeable in some crystals; no twinning observed.

Magnetite: This mineral is very abundant, a good deal of it being probably a product of the decomposition of the hornblende. It is irregularly scattered throughout the rock.

Apatite: Is very common in long acicular crystals; colour, pale-blue; cross-jointing well developed; penetrates other crystals, especially those of feldspar; extinction straight; refractive index moderate.

Calcite is present as a decomposition product of the feldspar.

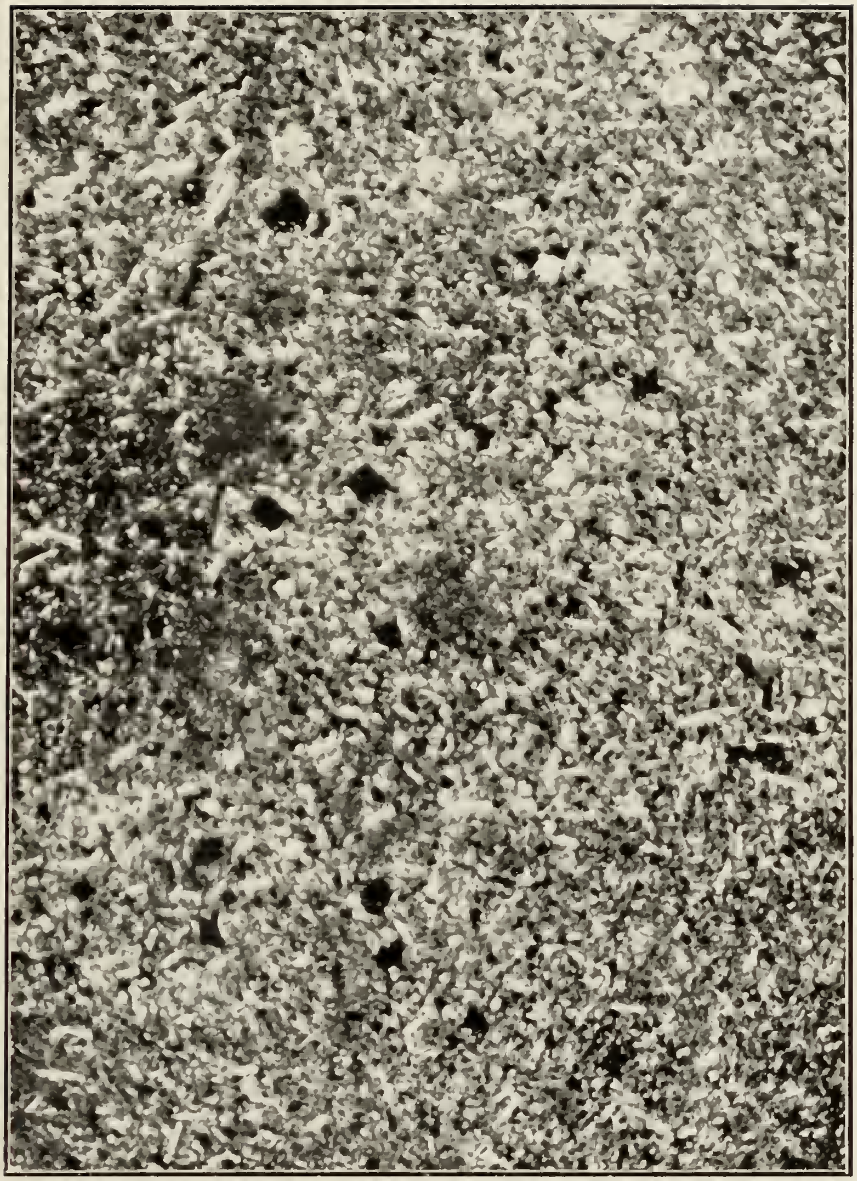
Remarks.—The groundmass of the rock is holocrystalline, and there seems to be an approach to the allotriomorphic character as far as the feldspars are concerned. The hornblende appears to belong chiefly to one generation, the phenocrystal generation being almost exclusively in evidence. The feldspar does not appear to occur as microlites, or only to a very small extent. The rock is a dioritic lamprophyre belonging to the type of that interesting group in which hornblende takes the place of the biotite. For this type of hornblende lamprophyre Rosenbusch uses the term "camptonite." ("Physiographie," p. 328.)

No. C1. Hornblende diorite.—This rock occurs as small pebbles in the gravels of the Clutha River. It is not common.

Macroscopic Examination.—A dense black rock speckled with white feldspars and black hornblende crystals.

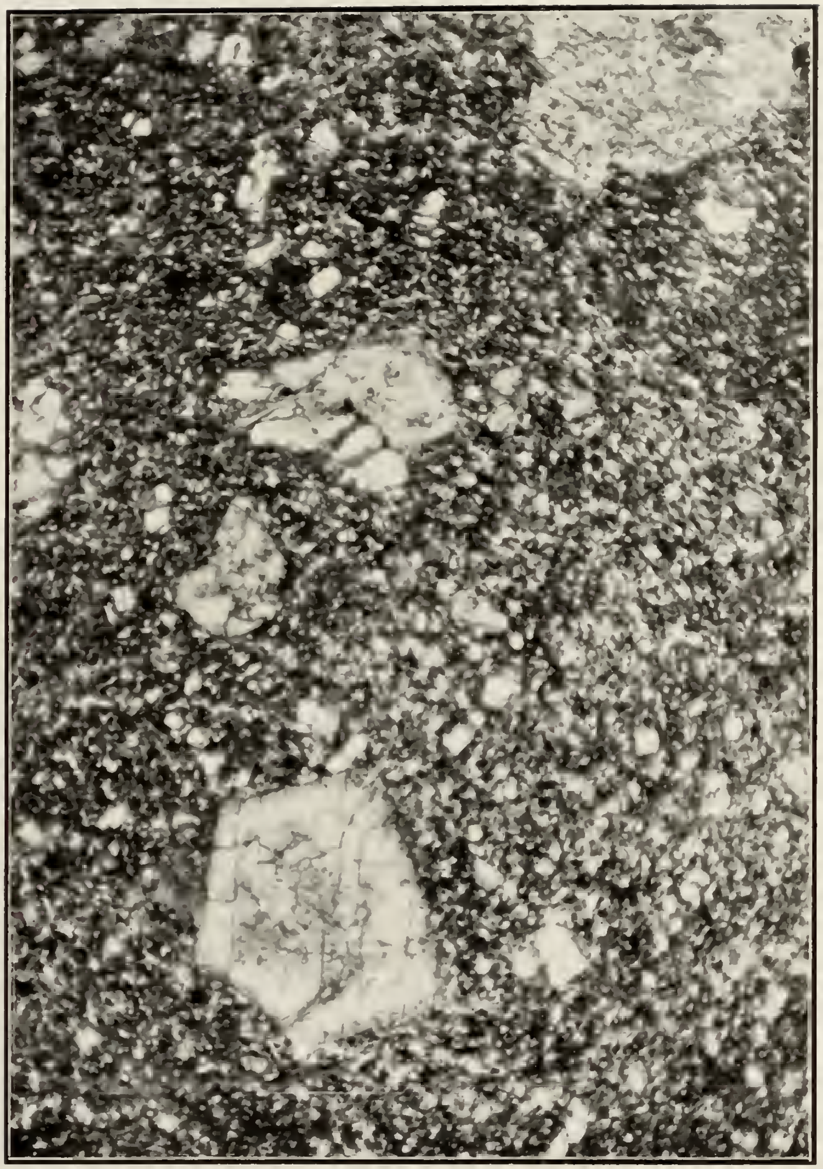
Microscopic Examination.—A holocrystalline aggregate of which the essential constituent minerals are feldspar and hornblende. Apatite, sphene, magnetite, calcite, and quartz are also present as accessory minerals.

Plagioclase: Plentiful, in large plates without defined boundaries; mostly labradorite and oligoclase; highly twinned on the albite law, less commonly on the pericline and Karlsbad laws; often decomposed to kaolin and calcite.



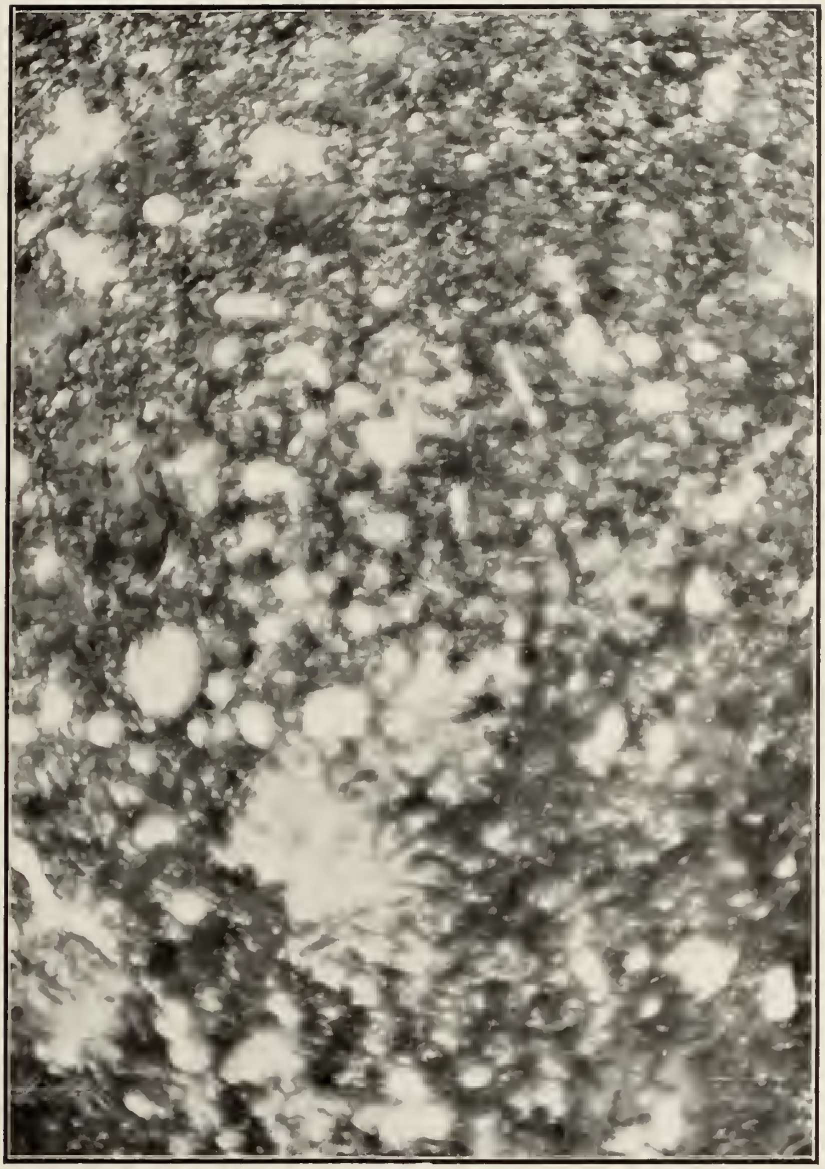
No. C 3. Olivine Basalt (Smooth).

Ordinary light; magnification, 34. *Photo. by A. McKay.*



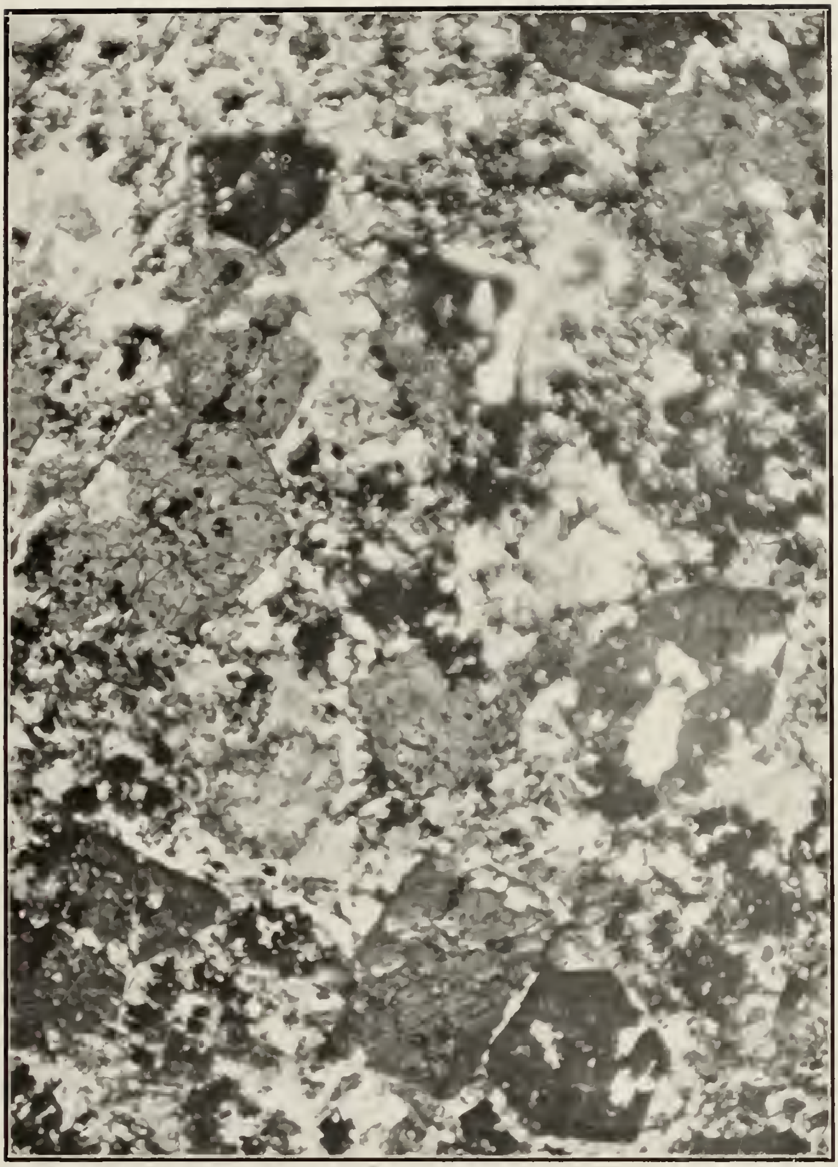
No. C 7. OLIVINE BASALT (PITTED).

Ordinary light; magnification, 34. *Photo. by A. McKay.*



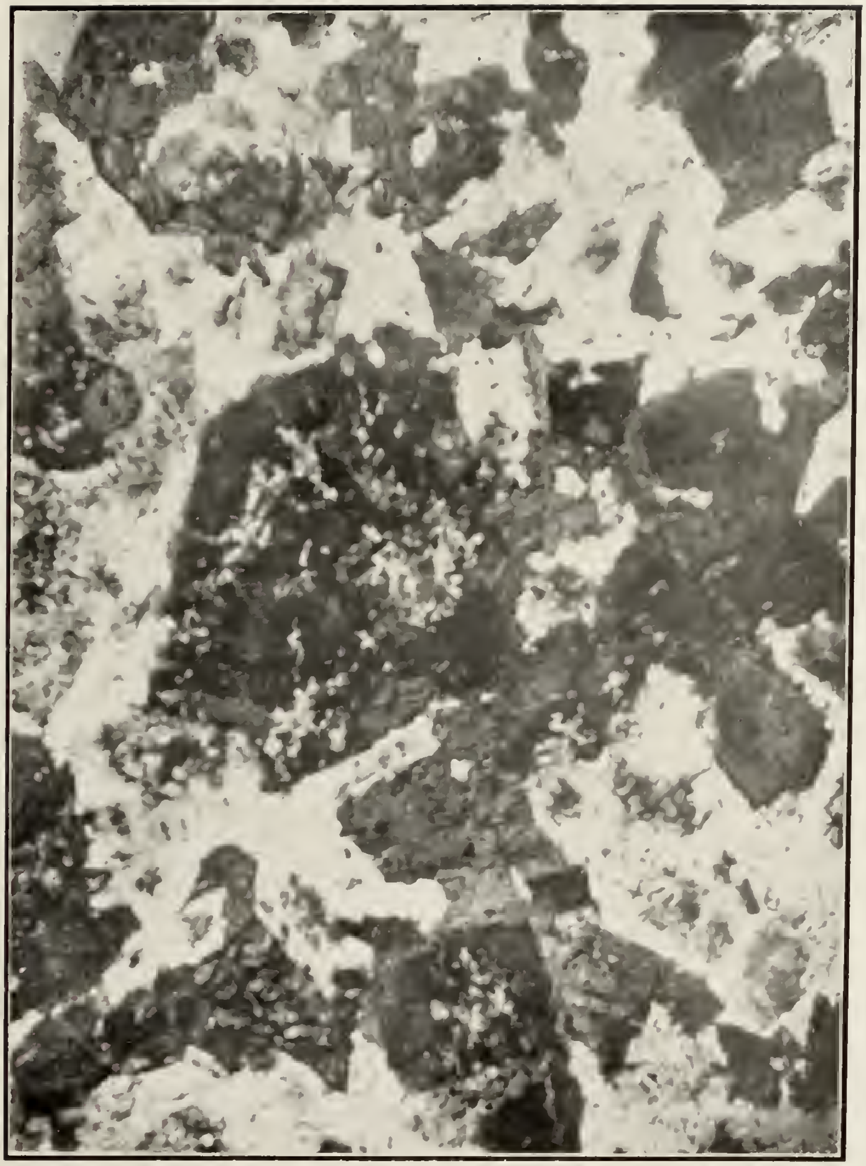
No. C13. Monchiquite.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



No. C 8. CAMPTONITE.

Ordinary light; magnification, 34. *Photo. by A. McKay.*



No. C 1. HORNBLENDE-DIORITE.

Ordinary light; magnification, 34. *Photo. by A. McKay.*

Hornblende : Very abundant ; plates large, green in colour with irregular outlines ; pleochroism marked, from yellowish-green to deep-green ; high birefringence and refractive index. No twinning noticeable. Ophitic structure is seen in which the hornblende crystals wrap round more or less completely the crystals of feldspar. Alteration to a product resembling uralite.

Apatite : Common in exceptionally large acicular crystals with the usual cross-jointing and inclusions ; colour, pale-blue.

Sphene : This mineral is present in dark wedge-shaped crystals with very high refractive index and moderate interference colours. Quartz as small grains is present but not common.

REMARKS.—The rock is holocrystalline with a typical hypidiomorphic structure. The feldspar and much of the hornblende are allotriomorphic. The presence of the ophitic structure, however, tends to show that in one or two cases the feldspar has not crystallized out after the hornblende.

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